

# **DEVELOPING A FRAMEWORK FOR BIM IMPLEMENTATION IN THE SAUDI ARABIAN CONSTRUCTION INDUSTRY**

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**A thesis submitted in partial fulfilment of the requirements of the  
University of Wolverhampton for the degree of Doctor of Philosophy (PhD)**

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## **ABSTRACT**

The construction industry in the Kingdom of Saudi Arabia (KSA) is faced with challenges of incessant delays, cost overruns and poor quality. The premise of the research reported here is that effective adoption and implementation of Building Information modelling (BIM) can contribute to the achievement of the necessary improvement. Against this backdrop, the aim of the research was to produce a strategic framework to underpin such adoption and implementation. It entailed investigation of the awareness of BIM, the extent of its use in KSA and the barriers to its more effective adoption and implementation. A mixed research approach was adopted, using a questionnaire survey and semi-structured interviews for collecting data. The questionnaire survey was used to obtain information on the awareness, barriers, drivers and status of BIM usage in the KSA construction industry, while the semi-structured interviews were designed to elicit the opinions of professionals and elucidate their own experiences in relation to the variables in this study. The data obtained were analysed using descriptive statistics, inferential statistics and thematic content analysis. The study found that the awareness of BIM in the Saudi construction industry is low and faced with inherent barriers that impede its successful application. These barriers were found to be a lack of knowledge of BIM, initial and running costs of implementation, a lack of training of personnel, and a fear of changing from the traditional methods of construction. The study identified strategies that could be used to address these challenges. These include enlightenment on the benefits of BIM application; creating awareness of BIM through workshops, seminars and conferences; training of workers; and the introduction of government intervention to enforce the application of BIM. In addition, this study identified the relevant factors that would enable the application of BIM in the Saudi construction industry to be meeting client's expectations and the requirement to use BIM technology, and using BIM because of the benefits it offers such as cost savings, efficiency, quality and increase in productivity. Regardless of these BIM drivers, however, the most important aim is to bring the stakeholders to commit themselves and invest in the necessary technology, tools and resources in order to improve construction processes. A strategic framework was developed to serve as a roadmap for BIM implementation. The framework also encompassed the key parties in the process and the specific roles to be played by them. The study concludes that the implementation of BIM could improve project performance in Saudi Arabia in terms of time, cost and quality.

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## **DEDICATION**

It is with immense pride that I dedicate this PhD Thesis to my Father and Mother for their unconditional kindness, devotion and endless support and encouragement. Their self-sacrifice throughout my research journey will always be remembered.

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## **LIST OF ABBREVIATIONS**

BIM	Building Information Modelling
BDS	Building Description System
BIS	Department For Business, Innovation And Skills
BOT	Build-Operate-Transfer
CAD	Computer Aided Design
DBB	Design-Bid-Build
EDI	Electronic Data Interchange
GCC	Gulf Cooperation Council (Now the Cooperation Council For The Arab States of The Gulf, but still known by its former name)
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GSA	General Services Administration
GTP	Government Tenders and Procurement
ICT	Information Communication Technology
IDM	Information Delivery Manual
IFD	International Framework Dictionary
KPI	Key Performance Indicator
KSA	The Kingdom of Saudi Arabia
MEED	Middle East Economic Digest
MEP	Mechanical, Electrical and Plumbing
NBS	National Building Specification
NTP	National Transformation Program

PDA	Personal Digital Assistant
PFI	Private Finance Initiative
PPP	Private-Public Partnership
RIBA	Royal Institute of British Architects
ROI	Return on Investment
SAR	Saudi Riyals
SAR	Saudi Railway Company
SPSS	Statistical Package for The Social Sciences
UAE	The United Arab Emirates
USD	United States Dollars
WPMS	Web-Based Project Management Systems
WTO	World Trade Organization
WWW	World Wide Web

# **CHAPTER ONE**

## **INTRODUCTION**

### **1.1 INTRODUCTION TO THE RESEARCH AND CHAPTER ONE**

This chapter provides an overview about the research undertaken and its outcome. Further it presents the background to the research study. Then the problem statement, the gap in knowledge, research questions and the aim, objectives and brief methodology of the research are discussed. Subsequent to this, the significance of the research and the research scope and limitations are discussed. Finally, the structure and organisation of the thesis are provided in the later part of the chapter. To conclude a summary of the chapter is presented at the end.

### **1.2 BACKGROUND OF THE STUDY**

One emerging technology and process within the construction industry can be identified as Building Information Modelling (BIM). BIM “is an innovative technology, whereby one or more accurate virtual models of a building are constructed digitally. They support design through its phases, allowing better analysis and control than manual processes. When completed, these computer-generated models contain precise geometry and data needed to support the construction, fabrication, and procurement activities through which the building is realised” (Eastman *et al.*, 2011, p 17). NBS (2018) add that BIM is a process for generating and the managing data as well as information exchange during the project lifecycle of a construction project. The most important output of this process is the digital description of every aspect of the construction project. These definitions of BIM encompass a great deal, starting from one technology to embracing the whole construction process.

As BIM involves people and construction project information working together effectively and efficiently through defined processes and technology, it is therefore regarded by many as a game changer in the construction industry with the potential of integrating all professionals to ensure collaborative working on projects through the use of digital technologies. Researchers such as Edwards *et al.*, (2015) suggest that BIM enhances life cycle processes and a collaborative way of working in the construction industry. Chen and Luo (2014) also report that BIM has the potential of transforming construction industry processes of design and construction, whereas Singh *et al.*, (2010), define BIM as an IT-enabled method for the integration of design, prototyping of virtual reality, simulations, distributed access, retrieval



and maintenance of the building data. Through BIM, the engineering data, schedules and design tools can be circulated effortlessly between consultants and that information can be modelled in 3D for the total facilitation of construction knowledge all through the lifecycle of a construction project (Arayici *et al.*, 2012).

### **1.2.1 The Global Construction Industry**

The global construction industry is inefficient, highly competitive, fragmented, cyclical and frequently operates on low margins (Yang *et al.*, 2010). The industry is also labour intensive, project-specific often underperforms, particularly in the delivery of its construction projects (Love *et al.*, 2011). Problems such as a shortage of skills, a lack of research and development and its current approach to the usage of tender price evaluations, are widely recognized (Meng, 2012).

Research shows that the same criticism can be made of the Saudi Arabian construction industry which is project-specific and involves team relationships that form and disband on a regular basis and is associated with many projects that suffer from rampant delays and cost overruns.

### **1.2.2 The Construction Industry as a Pillar of the Saudi Arabian Economy**

In Saudi Arabia, the construction industry is the largest and fastest growing sector within the most strategic country of the Arabian Gulf (MEED, 2010; Samargandi *et al.*, 2013). This growth rate notwithstanding, the Saudi Arabian construction industry is young compared with developed countries (Al-Otaibi and Price, 2009; Mitra and Tan, 2013). In the construction industry of Saudi Arabia, both the public and private sectors are major players. Further, the core of the construction industry within Saudi Arabia consists of public construction projects such as public roads, buildings, bridges, water infrastructure, domestic housing and facilities for recreation and leisure (Al-Shaikh and Chahine, 2010).

Both Shoult (2006) and Mitra and Tan (2013) have observed that within the Kingdom of Saudi Arabia, construction has largely developed in tandem with the rapid growth of the domestic economy, which has been fuelled by enormous oil revenues. As these revenues constitute around 80% of Saudi Arabia's total revenues, the level of construction activity has tended to correlate with oil prices, and can thus be regarded as one of the significant components of the national economy (Othman *et al.*, 2006). Saudi Arabia became a member of the World Trade Organization (WTO) in 2005, opening the construction market to international firms, which resulted in the country achieving the largest gross national product

(GDP) in the Middle East (Al-Ajlan *et al.*, 2006; Othman *et al.*, 2006). In addition to this achievement, affordable housing is one of the significant demands arising from the growing population of Saudi Arabia. Hence the kingdom's construction industry is poised for record growth in the near future (Taleb and Sharples, 2011; Al-jarboua, 2009). However, the international construction industry has a major impact upon the Saudi Arabian one, especially when there is a major boom in construction activities taking place in the country (Ali and Al-falah, 2010). According to a report by Forbes Arabia (March 2005) the investment designated by the public sector was anticipated to surpass \$495 billion US dollars over the next ten years from 2006-2015. Subsequently, according to the Oxford Business Group's Saudi Arabia Report (2009), expenditure on over 16,500 ongoing public construction projects from 2009 to 2016 was estimated to reach \$956 billion US dollars. It was reported by the Ministry of Planning in 2016 that the construction sector accounted for about 61% of GDP, thereby making it one of the most important contributors to the economy (Saudi Ministry of Economy and Planning, 2016; Ministry of Finance, 2017).

Accordingly, it can be said that the country's construction activity has experienced a boom of exceptional volume in the recent past, and this is set to continue as the industry undergoes rapid infrastructure expansion which includes the construction of new residential buildings, cities, airports, public and private buildings, schools, hospitals, roads, highways, bridges and dams (Saudi Arabia Ministry of Economy and Planning, 2011; Rashad, 2014; Saudi Ministry of Housing, 2014; spa.gov.sa, 2017). As a result of the aforementioned growth of the Saudi economy and the corresponding construction, the boom has created opportunities and incentives for international investors, construction experts and professionals, consultants and engineers to enter the Saudi construction industry, since most of the tendering of Saudi construction projects is conducted internationally. This has resulted in filling the gap between high demand and low availability through the influx of foreign workers and investment from multinational companies. Hence, there are many international consulting and construction firms operating in Saudi Arabia which are completely reliant on labour and teamwork from foreign countries (Al-Shaikh and Chahine, 2010), as there is a shortage of professionals such as contractors, sub-contractors, consultants, and engineers as well as skilled labour in Saudi Arabia to handle the huge construction boom in the country (Al-Mutiri, 2016; MEED, 2009).

Although the construction industry has attracted many international construction organizations and experts from around the world, the Saudi Arabian construction industry is still confronted with intractable problems, such as delays in the delivery of projects,

difficulties with procurement or tendering, lack of communication, poor planning, disputes, errors, time and cost overruns, changes in design, uncertainties in specifications and plans, cash flow problems, equipment and material shortages, and increased maintenance costs (Al-Sahli, 2011). Such factors add complexities and uncertainties to the reliability of the Saudi construction industry (Al-Barrak, 2004; Al-Otaibi and Price, 2009; Mitra and Tan, 2013). Al-Sultan and Al-Zaharnah (2009) carried out a survey to evaluate the performance of time on public sector projects of various types within Saudi Arabia. He found that 70% of these projects had experienced delays in terms of the time set for the project schedules. Assaf and Al-Hejji (2006) undertook a similar investigation into the projects funded by the Saudi Ministry of Housing and Public Works. They outlined 73 delay factors and ranked their importance according to the perception of each of the project participants, namely: owner, consultant, contractor and labourers. In around 70% of all the Saudi construction projects, delay in some form or other was indeed experienced with the accompanying knock-on effects. Mohammed (2007) investigated construction projects belonging to the public sector in terms of cost and found that more than 60% of the projects studied involved cost overruns. Furthermore, there are variations in the quality of public projects amongst government agencies because of the disparate methods that are utilized to measure quality and create value (Al-Jarosha, 2010; Al-thynian, 2010).

Many authors advocate the benefits of Building Information Modelling (BIM), as it has the capability to improve and enhance project efficiency, productivity and the quality of construction projects by providing more up-to-date and accurate information, reducing the number of incompatibilities and mistakes, and giving an accessible and graphic description of a construction project and its distinctive features to all stakeholders (Eastman *et al.*, 2011; Azhar *et al.*, 2012). BIM represents a collaborative environment in which the project team can work. It starts at the initial design phase, through estimating, scheduling, and project management. It begins with the clients requirement's, architects, planners and engineers, then once fully utilized, it involves the whole project team, including the contractor and the client or end user. With BIM, the construction industry is beginning to make some fundamental changes, not just to the way in which construction projects are “drawn up”, but how they are analysed, estimated/budgeted, scheduled, and managed, from conception to close-out, and beyond (Arayici *et al.*, 2011; Lee, 2013).

### **1.2.3 BIM as a New Process and Technological Construction Tool**

It is for the above mentioned reasons that Building Information Modelling (BIM) is proposed as a new processes and technological construction tool for combatting the challenges of construction, which could go a long way to help address the majority of the given problems concerning the Saudi construction industry, as it has been described as the main driver in the evolution from the traditional methods of working in the construction industry in over two decades (Eadie *et al.*, 2013). Further to this, Saxon (2013) states that BIM is an advanced digital technology which consists of a collaborative and innovative working system, thereby providing more efficacious methods for the design, creation and maintenance of the built environment. Moreover, there is the maintenance of quality of information from inception to occupation, operation, and maintenance: in other words, throughout the whole project lifecycle (Saxon, 2013).

As reported in the RICS Building Information Modelling Survey Report (BCIS 2011), BIM acts an interface between various different construction professionals for the achievement and delivery of complex project goals. Therefore, BIM is defined in the report as a technology which helps in the management of information on a construction project. Fundamentally, BIM focuses on the support and facilitation of integrated working methods and flow of information of a project to the point of its delivery. Further, it also deals with the collective use of semantically rich 3D digital building models which illustrates every different phase of the construction project lifecycle (Underwood and Isikdag, 2011). Besides this, there are numerous advantages provided by BIM technology, such as application scheduling, estimation of cost and controlling, control of programme, identification and exclusion of 3D spatial conflicts, design analysis support development, consistent drawing preparation, and accurate bills-of materials preparation (Robert, 2011).

According to Turner (1990), the construction industry is an enterprise in which one shows confidence in even the most unrefined examples of building construction. During the design, construction and management of modern contemporary buildings huge amounts of materials, resources and workforce are required over long periods of time. Therefore, the design of the architectural building plus the mechanical, electrical and plumbing aspects (MEP) are usually complex by nature. Generally, the project commences with the details of the design, then the technical specifications, ideas, experiences plus historical data are accepted for reviewing as well as appraisal by the project team. Hence, construction professionals such as architects, engineers and project managers consider the BIM technology as one of the most efficient

tools to date. Also with BIM there is a greater impact on the project design simultaneously at different phases of construction and this has a positive effect on the construction and operation of the project. Most importantly, BIM makes it easier to obtain project data on cost, time, scope and schedule swiftly from a high-quality, consistent and reliable system of referencing (Autodesk, 2007).

Thus, the implementation of BIM technology by construction organisations can be employed for reducing project costs in the design and construction phases as well as in the phase of project operation, and in addition can maximize the work quality, effectiveness and productivity of the construction processes (Kessinger, 2008). Accordingly, BIM is a construction industry tool which has emerged as a valuable operational technology through which data interoperability can be increased, collaboration between project participants can be developed and quality information of construction projects can be achieved. Similarly, it can also assist in revolutionizing the design and construction of large infrastructure projects. So, due to an increase in the awareness of the use of BIM and its associated technologies, many developed countries have made it a necessary requirement to utilize it in their construction industry practice.

#### **1.2.4 Associated Studies**

At the time of initiating this PhD research, there had been no comprehensive study conducted into this topic area of the use of BIM in the Saudi Arabian construction industry or into how the effective adoption of BIM can lead to the transformation of the Saudi Arabian construction industry. In the course of this PhD study, Sodangi *et al.*, (2017) and Banawi (2017) published the comprehensive findings of their research studies with regard to of BIM implementation, awareness and barriers within different sectors of the Saudi Arabian construction industry.

Sodangi *et al.*, (2017) based their research upon the level of subcontractors awareness and preparedness for BIM implementation in construction projects in the Saudi Arabian construction industry by the use of a questionnaire survey only. Whereas, Banawi (2017), researched the barriers to implement BIM in public projects in Saudi Arabia, with the use of a questionnaire survey and a case study. The difference between their work and this research study is that as well as the utilization of a questionnaire survey the author also concurrently made use of semi structured interviews and then went on to develop a framework for BIM implementation within the Saudi Arabian construction industry as a whole.

Furthermore, a study has been conducted by Gerges *et al.*, (2017), to determine the present status of BIM in the Middle East by exploring the extent of BIM implementation among stakeholders in the construction industry. Research has also been conducted by Ahmed *et al.*, (2014), their study was aimed at evaluating the awareness and experience levels of 4D planning and BIM in the construction industry in Qatar in addition to identifying the likely challenges to the general implementation of BIM with the use of a questionnaire survey for construction personnel in the construction industry of Qatar. Hussein *et al.*, (2017), conducted similar study on the application of BIM technology and to identify the desired benefits and challenges that limit BIM adoption within the Iraqi construction industry.

The preceding sections identify and justify research into this topic thereby leading to improved construction practices and outcomes.

### **1.3 PROBLEM STATEMENT**

Construction is a project-based activity, where every project has a unique environment, and the real challenge is to deal with unexpected changes in a flexible manner (El-Sayegh *et al.*, 2015; Aziz and Algan, 2017). The main barrier for BIM to be implemented and accepted is the recognition and execution and operation of BIM by construction organisations, as well as a stable framework for BIM implementation which takes into consideration the cost, time and managerial outcomes of implementing it (Succar, 2010). In fact, it is the cost and time factors that are the obligatory prerequisites, since the adoption of BIM by owners is imminent once it has been proven to be effective.

Several studies have been conducted into BIM and its implementation, particularly in the developed world, in such countries as the UK, USA, Australia and Canada. These studies include Arayici *et al.*, (2012), Won *et al.*, (2013), Smith (2014), Tahrani *et al.*, (2015), Bui *et al.*, (2016) and Sreelakshmi *et al.*, (2017). However, **unlike the developed world, not much research work regarding BIM has been conducted in Saud Arabia. The limited studies conducted on BIM do not take into consideration the extent of the use of BIM in the construction industry of Saudi Arabia or did they propose strategies for the effective adoption of BIM to improve construction operations. It is, therefore, to this end that this research is directed. This proposed research aspires to examine and analyse the awareness of the benefits of BIM, and the barriers to its adoption, and to propose a framework that could help the construction industry of Saudi Arabia, as well as the**

**construction industries of other developing countries that merit the application of BIM, to respond to the challenges of BIM adoption.**

#### **1.4 THE GAP IN KNOWLEDGE**

There are two major areas with existing gaps in knowledge: the technological and sociological challenges which accompany the implementation of BIM process and technology in the context of Saudi Arabian construction organisations. Ciborra (2004) as a general rule explains the inconsistencies in the understanding of change within organisations and technological innovation. For such a consecutive and progressive channel there is no involvement of dialogue between downstream organizational processes and technology apart from a set of standard engineering processes in Saudi construction organisations (Al Sulaihi and Al Gahtani, 2013). Hence, conventionally, at the pre-design stage the main focus is on the functionality and performance of a project, and process limitations are seldom taken into account. Therefore effective working practices and operational factors such as effectiveness of planning, business efficiency, project management leadership, policy and strategy, resource management and risk assessment, as well as project lifecycle management processes and benchmarking performance, are imperative and should be in place (Usmani and Al-Ahmari 2012).

So, the main emphasis is currently on the development of new teachings of innovative working processes and novel technology, or for the selection of innovative technology to fit the context of the construction organisation, and this has been the main approach towards applying new innovative working processes as well as the novel technology as BIM processes and technology provides several benefits and efficiency gains. These include a faster design processes, effective reuse of information and overall client satisfaction (Almuntaser, *et al.*, 2018). However, what is more important is that such views from the aforementioned authors (Al Sulaihi and Al Gahtani, 2013; Usmani and Al-Ahmari 2012) specify the process of the adoption, implementation and use of technology in the Saudi Arabian construction industry. Amongst these perspectives are distinguishable gaps in the understanding of the mechanisms which generate the conditions for the execution of innovative technology (Sodangi *et al.*, 2017; Almuntaser, *et al.*, 2018).

At present Saudi Arabia is facing a construction boom so that the needs of its increasing population and the ever-increasing number of visitors into the kingdom are met. However,

the country's construction industry is considered to be one of those industries where there is less adoption of new innovative technologies in comparison to other industrial sectors. Hence there is a need for successful and innovative processes and novel technology to be implemented in the construction industry to solve the construction problems faced by Saudi Arabian construction organisations. As a result, the characteristics of the Saudi construction industry have been presented as the justification for this matter. This predominantly concerns the bespoke disposition of the construction industry in general and of its products and services and the heterogeneous nature of its boundaries of knowledge along with a project team that is transitory (Anumba and Pulsifer, 2010). The new and analytical integrity of the development of innovative technological solutions is the reflection of a lingering rollout of BIM solutions on projects in the Saudi construction industry (Al-Mutiri, 2016). Indeed, a change of technology as well as a change of structure, task and personnel influences the result of the implementation of BIM. Accordingly, the study of the Saudi Arabian construction industry as a whole and individual Saudi Arabian construction organisations will assist in observing how they are influenced and affected by the advent of BIM and the solutions it offers through its associated technologies. This confirms the prerequisite of further investigation as there is a contradiction in the limited literature of BIM adoption and implementation in the Saudi Arabian construction industry, implying a gap of knowledge within the environment of the Saudi Arabian construction industry.

## **1.5 JUSTIFICATION OF THE STUDY**

The aim of the current study was to investigate the implementation and adoption of BIM technology and process in the construction industry in the Kingdom of Saudi Arabia. An extensive review of the literature indicated that no previous studies had been undertaken specifically with regards to BIM implementation and adoption in the construction industry of Saudi Arabia. The goal of the study was to provide insight into the awareness, benefits, barriers and strategies to the adoption of the innovative BIM technology within construction organisations in Saudi Arabia, given the vast investment in new construction projects. According to AlSehaimi *et al.*, (2009), previous efforts to solve the problems in the Saudi Arabian construction industry has consisted of the implementation of lean construction and its tools which included; preventive maintenance, safety improvement programs, visual inspections, continuous improvement programs, daily huddle meetings, total quality management, use of prefabricated materials, target value design, concurrent engineering, just-in-time approach, plan of conditions and work environment in the construction industry,



computerised planning system or ERP, information management system, 5S, six sigma and Kanban. However, the lack of lean construction adoption in the Saudi Arabian construction industry has been constrained by various factors such as poor equipment, an unskilled workforce, and ineffective planning (Sarhan *et al.*, 2017).

Prior to this business process re-engineering (BPR) which was a new and innovative approach in management at the time was introduced to the Saudi Arabian construction industry (Abdulhadi, 1997). This approach placed new emphasis on process to improve management practice and to improve the quality of work in practice by solving practical problems and create new knowledge. Nevertheless, this also failed to deliver due to the BPR approach, the tools used, and resistance to change management (Abdul-Hadi *et al.*, 2005; Al-Sultan, 2001).

Considering that, the Saudi Arabian construction project success particularly in the IT sector is a mere 48% –according to Alfaadel, Alawirdhi and Al-Zyoud (2012) and Assaf and Al-Hejji (2006), this posited that the Saudi Arabian construction industry is slow in adopting new innovative technologies in comparison to other industrial sectors. Furthermore, Lou and Alshawhi (2009) found that Saudi construction industry companies are often set in their old ways of doing business, and consequently see the change to an electronic environment as unproductive. Similarly, Ikediashi *et al.*, (2014) confirmed that Saudi construction companies lack knowledge, management and experience in project lifecycles, which makes it difficult for them to compete with technologically advanced international companies. As such, the industry is faced with inherent problems such as delays in execution of work, cost overrun, poor project management, design mistakes and discrepancies, design change orders, lack of collaboration among project participants, bureaucracy, and poor site management (Assaf and Al-Hejji, 2006). Such factors add complexities and uncertainties to the realization of the proposed plans and visions of the Saudi construction industry (Al-Barrak, 2004; Al-Otaibi and Price, 2009; Mitra and Tan, 2012).

Henceforth, data collection and analysis procedures are also justified. Analysis of the data from the study provided significant informative data related to current BIM technology adoption and implementation practices. This research was therefore justified on the grounds that the findings would:

- i. Develop a framework relating to the strategic adoption of BIM as a process and technology (as provided in Chapter 7).
- ii. Offer recommendations for improving the policies, incentives and programmes of the Saudi Arabian Government for encouraging the adoption of BIM technology by Saudi Arabian construction organisations.
- iii. Offer recommendations for improving the BIM technology adoption and implementation strategies by Saudi Arabian construction organisations.

As Saudi Arabia is for the first time facing a need to optimize its national expenditure in order to maximize the value of its spending, ultimately, the central issue to be analysed and discussed in this research is how an enhanced understanding of BIM technology, its benefits and its implementation in Saudi construction organizations can be gained.

## **1.6 RESEARCH QUESTIONS**

In an attempt to fill these gaps of knowledge, this research project is being undertaken to answer the following fundamental research questions:

1. What is the level of awareness on BIM in the Saudi construction industry?
2. How could BIM be successfully implemented in the Saudi construction industry?

## **1.7 AIM AND OBJECTIVES OF THE RESEARCH**

In order to address these research questions and to make contribution to knowledge which is necessary to address the research problem, the aim of the research is to study the extent of the use of BIM in the Saudi Arabian construction industry, and the barriers to its use, and to propose strategies (including a framework) for the effective implementation or adoption of BIM.

For achieving the research aim, the following objectives are pursued in the study:

- 1.to identify the functionalities, implementation, advantages and disadvantages of BIM from a comprehensive literature review;
- 2.to empirically study the awareness of BIM in the Saudi Arabia construction industry;
- 3.to empirically investigate the extent and nature of the use of BIM and associated barriers in the Saudi Arabian construction industry;

4. to develop and validate a framework for adopting and implementing BIM in the Saudi Arabian construction industry;
5. to draw conclusions and make recommendations to the Saudi construction industry regarding the future use of BIM in order to achieve better construction outcomes.

## **1.8 OVERVIEW OF THE RESEARCH METHODOLOGY**

This research carried a comprehensive literature review with regard to BIM technology for objective 1 (Creswell, 2013). The literature review presents a critical analysis of the Saudi construction industry, experiences of the use of BIM technology in the global construction industry, and also awareness and barriers to implementing this technology in the Saudi Arabian construction industry. Then subsequently the research adopted a mixed methods approach through the combined use of quantitative and qualitative strategies by conducting a questionnaire survey to study the awareness of BIM technology in the Saudi Arabian construction industry for objective 2.

Achieving objective 3 involved conducting semi-structured interviews in order to collect the primary data. It also entailed the analysis of the collected primary data using inferential statistics for the quantitative data and thematic content analysis for the qualitative data. Objective 4 consisted of developing a framework specifically implementing or adopting BIM technology in the Saudi Arabian construction industry based on the findings of the research. Finally, to fulfil objective 5, all of the above-mentioned made it possible to provide justification, draw conclusions and make recommendations regarding the future use of BIM technology in the Saudi Arabian construction industry.

## **1.9 SIGNIFICANCE OF THE RESEARCH**

There are two main issues that drove this research (Alenazi and Adamu, 2017; Sodangi *et al.*, 2017): 1) the significant contribution of BIM to the Saudi Arabian construction industry; and 2) the underdeveloped research area of BIM implementation within Saudi Arabia.

The first issue concerns the significant role of BIM technology within the construction industry of Saudi Arabia. The main problematic factors of the Saudi construction industry can be confronted through the use of BIM and its associated innovative construction technologies to support this industry (Alenazi and Adamu, 2017). Many construction industry concerns have been addressed through the introduction of BIM in construction, such as the development of predictable project results from the pre-design phase through to construction

with the utilisation of tools and processes associated with BIM; supporting a working culture model that is collaborative in nature; overcoming deficiencies in team coordination; promoting interdisciplinary collaboration amongst the different types of project participants for the optimization of the project delivery processes; and refining the value and efficiency of information shared amongst project stakeholders (Azhar *et al.*, 2012; Korkmaz *et al.*, 2012; Eastman *et al.*, 2011; Babic *et al.*, 2010; Grilo and Jardim-Goncalves, 2009).

The use of BIM has flourished in many developed regions, including those of North America, Asia Pacific and Western Europe, and is on the increase in the Arabian Gulf countries (Gerges *et al.*, 2017). Pike Research (2012), a consulting team which provides in-depth analysis of clean technologies in the global market, has characterized BIM as an emerging technology that is evolving rapidly. As such it has been predicted that the annual revenues from BIM products and solution services worldwide will increase considerably from \$1.8 billion US dollars in 2012 to almost \$6.5 billion US dollars by 2020 (Pike Research, 2012). The UK government's chief construction advisor has stated that the introduction of BIM could initiate the integration of the industry's related technologies, which is one of the construction industry's many challenges (Morrell, 2011). There is also great potential for the elimination of waste, which would then decrease costs and see an increase in profits as well as encouraging the greater use of offsite prefabrication (IGT, 2010).

The second issue, mentioned by many different authors, is that numerous barriers impede the implementation of BIM (Rosenberg, 2006; Yan and Demian, 2008; Andre, 2011; Azhar *et al.*, 2011). Since the implementation of BIM is still a developing and ongoing process in the construction industry in general, there are currently no proven guidelines which are suitable for any particular types of construction projects. So, for the implementation of BIM, extensive study is still a debatable issue. Therefore, the adoption of BIM in Saudi Arabia is still lagging behind expectations (Sodangi *et al.*, 2017), as the main causes for resistance to the adoption of innovative technologies within the Saudi Arabian construction industry are resistance to change, and conflicts against altering traditional methods of working, as there are impacts on the culture of project-based organisations in construction projects. Such issues emerge from the culture present in the multi-operational organisations engaged in construction projects. In addition to this, the process of adoption during a period of transition is related to organisational capabilities (BuildingSmart, 2011; Awwad, 2013; Alnaser and Harty, 2016; Banawi, 2017). The issues raised above have been addressed in the construction

industries of other countries by adopting change as part of their working culture (Khan *et al.*, 2014). Change management can be seen to extend the interaction between leadership and staff, given the effect of change management on human resources by effecting behavioural changes as well as organisational working processes and practices (PMI 2012).

However, due to the implementation of BIM, there is a lasting impact on the working culture of project-based construction organizations and the culture prevailing in independent organisations. Therefore, in order to successfully implement BIM in Saudi construction organisations, the country's construction industry as a whole needs to be addressing the problem of the barriers that hinder its implementation (Mitra and Tan, 2012). And so initially it would be a fundamental requirement to comprehend the cultural phenomena and participant interactions in the project-based organisations in the new BIM environment.

#### **1.10 RESEARCH SCOPE AND LIMITATIONS**

The fundamental issue to be investigated in this research is how a greater understanding of BIM technology and its implementation in Saudi construction organizations can be gained. It is for this reason that the scope of the present research is limited to adopting modern day BIM processes and technology with the aim of being productive, efficient and able to deliver projects on time and on budget, within the construction industry of the Kingdom of Saudi Arabia. Consequently, it is for these reasons that the present research is limited to the implementation and adoption of BIM processes and technology within both the public and private sectors of the construction industry of Saudi Arabia, with the goal of providing comprehensive results that would offer a conclusive understanding of those variables that most influence the utilisation of BIM processes and technology to streamline the business processes, as well as improve methodologies of site management and the total facilitation of construction knowledge all through the lifecycle of construction projects in the Saudi Arabian construction industry. Altogether, this research is a detailed and reflective documentation of achieving optimum BIM technology usage within the construction industry of the Kingdom of Saudi Arabia.

#### **1.11 STRUCTURE OF THE RESEARCH THESIS**

This research report is organized into nine chapters. Chapter one provides an overview of the entire research process. It begins by setting out the background to the research. This is then followed by the problem statement, the gap in knowledge, research aim, objectives, and a

short explanation of the research methodology adopted. This leads to the significance of the research. Finally, the summary of the chapter is stated.

Chapter Two reviews the literature regarding the background to the Saudi Arabian construction industry. It presents an overview of the literature on the nature and characteristics of Saudi Arabian infrastructure, and its importance to economic development, and assesses the potential problems that influence the country's construction industry.

Chapter Three reviews the literature on BIM in the construction industry. The chapter presents an introduction to BIM, and then goes on to discuss the principles of how BIM is developed to aid projects in the construction industry. It also presents an evaluation of studies on how BIM is used in countries across the globe with a specific focus on BIM and the construction industry of Saudi Arabia. This chapter goes on further to review the benefits of BIM as well as the barriers to its adoption within the construction industry in general, besides the challenges of BIM adoption and implementation particularly in the Kingdom of Saudi Arabia.

Chapter Four presents the research methodology which has been utilized to conduct the research study. Here it discusses the quantitative and qualitative research methodologies employed for the study. It also discusses the particular reasons why the mixed method approach was embraced. The chapter further states how the different types of data were collected for the research and then analysed to address the research objectives.

Chapter Five presents the findings of the quantitative data analysis which was carried out using the statistical software SPSS to conduct cross tabulation and correlations to analyse the relationships amongst the variables and evaluate the awareness of BIM, and to determine the barriers to the use of BIM in the Saudi Arabian construction industry.

Chapter Six presents the findings of the qualitative data analysis which was undertaken by thematic content analysis method to establish the issues for the adoption of BIM in Saudi Arabia, and other related issues such as the benefits of BIM and the type of strategies to support BIM in the construction industry of Saudi Arabia from the viewpoint of Saudi construction professionals.

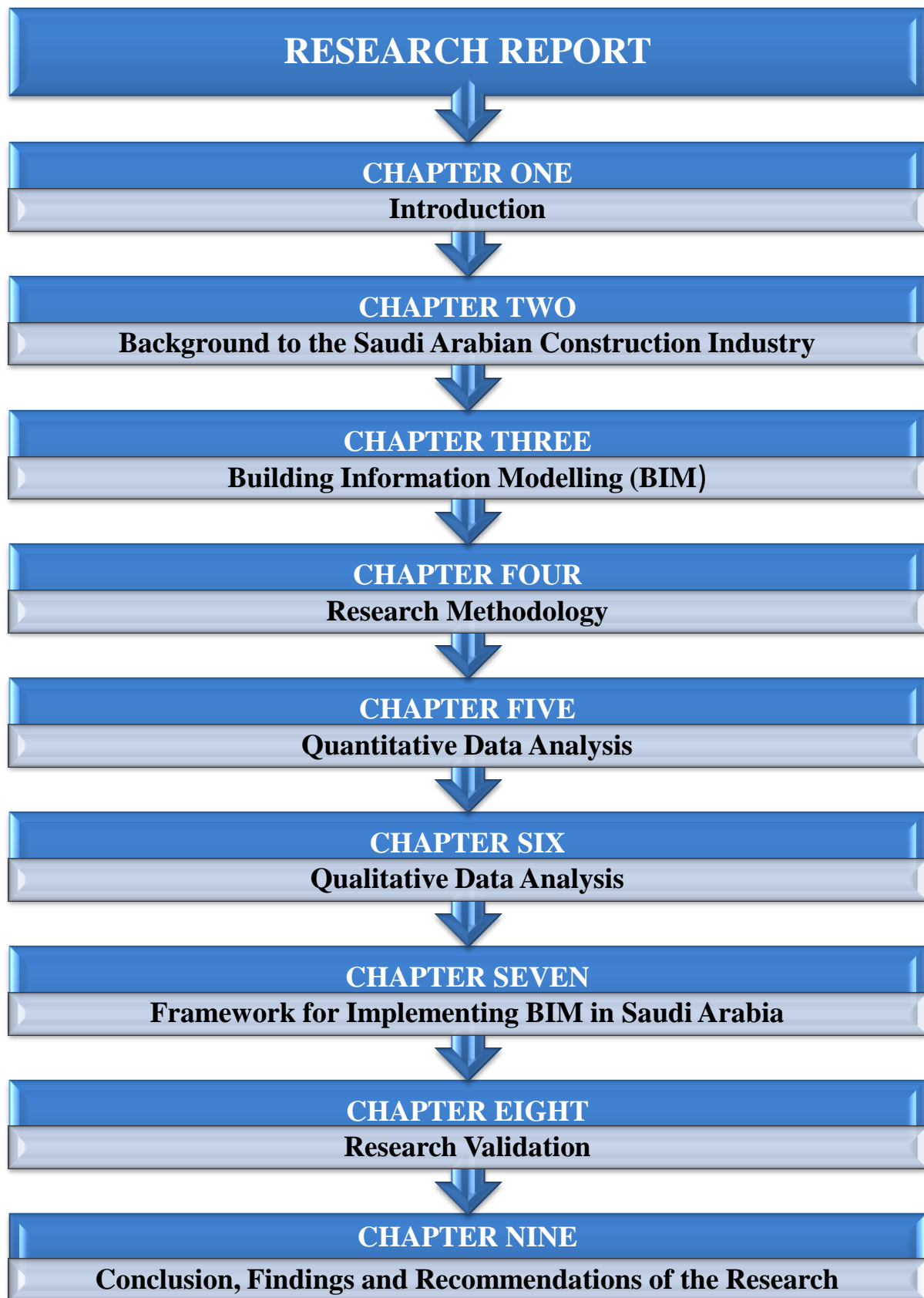
Chapter Seven presents the strategies for implementing BIM in the Saudi Arabian construction industry, based on the findings of both the quantitative and qualitative data analysis and those identified from the literature review. Then successively a framework is

created based on the relationships ascertained from the research findings and the literature review is developed. All the component parts of the framework are discussed as to how it could be utilized by the whole of the Saudi Arabian construction industry for the adoption and implementation of BIM.

Chapter Eight presents the research validation of the findings and an assessment of the proposed framework with the expert opinions of Saudi Arabian construction industry professionals.

Chapter Nine presents the findings, conclusions and recommendations of the research, outlining the key findings contributions, and limitations, making recommendations for BIM policies and practice, and also proposing recommendations for future research development.

The structure of this research thesis and the organization of the chapters is illustrated in the form of a diagram as set out in Figure 1.1.



**Figure 1.1: An Outline of The Research Thesis Structure**



## **1.12 SUMMARY OF CHAPTER ONE**

This chapter has presented an overview of the thesis, with discussions centred on the background to the research which aims to study the extent of the use of BIM in the Saudi Arabian construction industry as well at studying the barriers to its adoption and proposing strategies for its implementation within the Saudi construction industry. This was then followed by the problem statement, the gap in knowledge. Further to this, the research aims, objectives and overview of the research methodology were briefly discussed. The significance of the research and a summary of how the research thesis is structured and organized was also presented.

The research will subsequently consist of a critical review of the literature that will form the foundation of the research methodology in order to gather primary empirical data for the research. The empirical data will be analysed, and the findings will be used to propose strategies for BIM adoption and develop a framework for BIM implementation in the Saudi Arabian construction industry. Then finally the conclusion, findings and any recommendations will be presented in this thesis.

# **CHAPTER TWO**

## **AN OVERVIEW OF THE SAUDI ARABIAN CONSTRUCTION INDUSTRY**

### **2.1 INTRODUCTION TO CHAPTER TWO**

This chapter presents a critical review of the literature of the Saudi Arabian construction industry. In this review, the factors which affect its poor performance and the difficult challenges that have a negative impact upon Saudi construction projects are identified. This has been done in part to fulfil some of the research objectives and to provide a comprehensive background to the research subject area. Thus, the chapter begins with an overview of the Kingdom of Saudi Arabia; subsequent to this is an overview of the Saudi Arabian construction industry and a discussion of the latest major construction and infrastructure projects to be initiated in the kingdom as well as the problems being faced. It goes on further to discuss the use of computer-based technology and the influence it has had upon the Saudi Arabian construction industry and concludes with a summary of the findings of the literature review.

### **2.2 OVERVIEW OF THE KINGDOM OF SAUDI ARABIA**

The Kingdom of Saudi Arabia is a sovereign Arab state located in the Middle East between the Arabian Gulf and the Red Sea. It covers a massive geographical area as its growing population is spread across a region larger than two million kilometres squared, making the kingdom one of the world's least densely populated countries (Al-jarboua, 2009). Over the last forty years the country has grown from groups of traditional villages into a modern metropolis of lively cities with the citizens experiencing and benefiting from an advanced level of development (Al-Surf and Susilawati, 2011). The largest urban areas are the capital city Riyadh, with a population of 7.31 million residents; Makkah, with 7.47 million residents; the Eastern Region, which has 4.41 million residents; and Al Medina Al Munawarah with 1.91 million residents (Ministry of Economy and Planning, 2013). According to the census of 2012, Saudi Arabia consists of 13 administrative regions. Figure 2.1 illustrates the Kingdom of Saudi Arabia and the surrounding countries in the region.



**Figure 2.1: Map of The Kingdom of Saudi Arabia and its Surrounding Countries**

(Source: [mapsof.net/saudi-arabia/saudi-arabia-regions-map](http://mapsof.net/saudi-arabia/saudi-arabia-regions-map), 2017)

### 2.2.1 Saudi Arabian Law and Constitution

The central institution of the Saudi Arabian Government is the monarchy, which is governed on the basis of Islamic law (Shari'ah). The Council of Ministers, who are appointed by and responsible to the king, have the responsibilities of formulating and overseeing the implementation of internal, external, financial, economic, educational and defence policies, and general affairs of state (Abdulaal, 2011).

### 2.2.2 Saudi Arabian Economy

The Kingdom of Saudi Arabia has experienced a high level of economic growth which has led to economic prosperity in the country and as a result urban development has increased rapidly over the past four decades. The discovery and commercial exploitation of crude oil in the 1930s, along with the simultaneous establishment of a construction industry has

transformed the traditional societies in the Kingdom of Saudi Arabia into having a standard of living and lifestyles that are similar to, if not higher than those in many developed countries (Mubarak, 1999). This transformation has been brought about by extensive government planning and investment for establishing the social and physical infrastructure of the country (Al-Shammari, 2009).

Since December 2005, Saudi Arabia has been a member of the World Trade Organization (WTO). This reflects the role of the kingdom as a major player in the international economy and as a result its accomplishment in drawing foreign investment into the country (Economy Watch, 2011).

### **2.2.3 Saudi Arabia's Valuable Natural Resources**

Saudi Arabia has ample natural resources that include crude oil, gas, petrochemicals, mineral deposits and precious metals. The country alone reportedly holds more than 21 per cent of global oil reservoirs (Saudi Arabia Market Information Resource and Directory, 2011). Furthermore, Saudi Arabia's proven gas reserves stood at 253 trillion cubic feet in 2007. This level of proven gas reserves signifies almost 4 per cent of world reserves (Saudi Arabia Market Information Resource and Directory, 2011).

### **2.2.4 Saudi Arabia's Environmental Challenges**

Saudi Arabia is one of the world's most environmentally challenged countries, with a harsh, hot, dry desert climate. The absence of permanent sources of water (such as rivers or lakes) makes the situation even more challenging. The climatic conditions, topography and limited water supply have hindered urban development (Al-jarboua, 2009). However, huge efforts have been made to face this challenge of water demand, by building 33 desalination plants, and hence, Saudi Arabia is the largest producer of desalinated water globally (El-Ghonemy, 2012).

## **2.3 THE CONSTRUCTION INDUSTRY OF SAUDI ARABIA**

The construction sector is a major player in Saudi Arabian industry. Huge infrastructural development projects in the construction industry of Saudi Arabia started in the 1970s and began to flourish in the early 1980s as numerous different infrastructure projects were needed in order to modernize the Kingdom of Saudi Arabia with ambitious plans which would provide the infrastructure that was lacking in the kingdom. According to a report by Business Week (2006), USD \$237.4 billion dollars was dedicated for investment in construction

projects in Saudi Arabia for the upgrading of the housing, hospital and education sectors, electrical services, water facilities and road networks over the next decade in Saudi Arabia. Successive to this, the US – Saudi Arabian Business Council (2009) reports that the construction sector of Saudi Arabia stated that the total number of construction projects in progress in the Kingdom of Saudi Arabia were valued at USD \$4.9 trillion dollars, and 687 of these projects were at the execution phase. Furthermore, according to the government of Saudi Arabia in 2013, infrastructure and construction projects were estimated to be worth more than SAR 28.6 trillion Saudi riyals (approximately USD \$7.63 trillion dollars) and in the Arabian Gulf region it is considered to be the largest market for construction (Ministry of Economy and Planning, 2013; Al-rashed and Asif, 2014).

As recently as the Spring and Summer of 2017, the Saudi Crown Prince and defence minister who also acts as the serving First Deputy Prime Minister, Mohammed Bin Salman announced through the Saudi Press Agency (an official Saudi government department) that there are key policies and investment programs that should help to boost construction. Under the National Transformation Program (NTP) 2020 and the Saudi Arabia Vision 2030, the Saudi government plans to develop sea ports, railway lines, airports and manufacturing facilities, with the aim of reducing the country's dependency on the oil sector. Under the NTP 2020, the Saudi Arabian government plans to invest SAR 268.0 billion Saudi riyals (USD \$71.5 billion dollars) for the development of the country's transport infrastructure and tourism industry. Furthermore, under the country's Vision 2030, the government plans to make Saudi Arabia a global trade hub (spa.gov.sa, 2017). Along with this, the Saudi government has also announced plans to fund mega large-scale infrastructure projects aimed at attracting foreign and private investment. The construction of most of these mega large-scale infrastructure projects will be on a Private Finance Initiative (PFI) or Private- Public Partnership (PPP) basis. Besides, these mega projects will all be based on sustainable building practices and Green Building concepts which encourage design, construction and operation using clean energy sources, efficient use of water, improved indoor air quality, sustainable building material and connectivity of sustainable infrastructure and buildings (spa.gov.sa, 2017). The pipelines of a few selected public mega infrastructure projects are listed in Table 2.1.

**Table 2.1: Mega Public Infrastructure Projects In The Kingdom of Saudi Arabia  
(2010-2017)**

<b>Public Mega Infrastructure Projects to be Initiated in the Kingdom of Saudi Arabia</b>			
<b>Construction Project Name</b>	<b>Total Area to be Covered</b>	<b>Cost of Project</b>	<b>Project Summary</b>
<b>NEOM Mega City</b>	This will cover a total area of 26,500 square kilometers that stretches from northwest Saudi Arabia over the borders into Jordan and Egypt (spa.gov.sa, 2017).	The project will be backed by more than USD \$500 billion dollars from the Saudi Arabian government, its sovereign wealth fund and investors from international and local levels (spa.gov.sa, 2017).	The ambitious plan includes a bridge crossing the Red Sea and across the Gulf of Aqaba close by the maritime trade routes which use the Suez Canal. Across the three countries this area is conceivably the first private business zone, consisting of a futuristic city which will concentrate on industries such as advanced manufacturing, biotechnology, energy and water, food and entertainment activities (spa.gov.sa, 2017).
<b>Entertainment City</b>	It will be constructed in an area of 334 square kilometers. It will be located in Al Qidiya, to the southwest of the Saudi capital city, Riyadh. (spa.gov.sa, 2017).	The Public Investment Fund of Saudi Arabia (PIF) will be the main investor in the project (spa.gov.sa, 2017).	This project is expected to be one of the biggest mega projects of its type in the world. It will be the largest quality cultural, sports and entertainment city, including a safari area. It is aimed be an outstanding cultural landmark and a significant hub for meeting the cultural, recreational and social needs of future generations in the Kingdom of Saudi Arabia (spa.gov.sa, 2017).
<b>The Red Sea Mega Tourism Project</b>	This will consist of the construction of luxury exotic eco-beach resorts on 50 islands off the Saudi Arabian Red Sea coast, between the cities of Amlaj and al-Wajh (spa.gov.sa, 2017).	The Public Investment Fund of Saudi Arabia (PIF) will provide initial investment for the Red Sea Project which will create 35,000 jobs related to development works and add SAR 15 billion Saudi riyals (equating to approximately USD \$4 billion dollars) to the kingdom's economy (spa.gov.sa, 2017).	This will pioneer the diversification of the Saudi leisure industry by contributing to a positive shift in the concept of luxury tourism and hospitality in the Kingdom of Saudi Arabia (spa.gov.sa, 2017).
<b>The New Jeddah Downtown</b>	It is anticipated that the project will cover approximately 5 million square meters and the development will be divided into six main parts: new homes; social and cultural centers; new	The redevelopment of Jeddah's waterfront corniche will be financed by the Public Investment Fund (PIF) of Saudi Arabia. The project will contribute SAR 18 billion Saudi riyals (this equates to	This project consists of the redevelopment of Jeddah's waterfront corniche, to create an exclusive and distinctive residential, commercial and tourist district, in addition to seaside activities in coastal areas, and walking routes along an exclusive yacht and boat pier (spa.gov.sa, 2017).

	museums; business and innovation areas; gardens, leisure and sports centers with amusement parks; and a wide range of hospitality facilities such as hotels, restaurants and cafes, and retail spaces (spa.gov.sa, 2017).	approximately USD \$4.8 billion dollars) of investment over 10 years (spa.gov.sa, 2017).	
<b>The King Abdullah Economic City</b>	With a total development area of 173 square kilometers or 66.8 square miles, the city is located along the coast of the Red Sea, around 100 km north of Jeddah (kaec.net, 2013;2017).	This construction will cost USD \$100 Billion Dollars and will require a huge amount of investment from national and also international sources investment as it is to be constructed completely on vacant desert land (kaec.net,2013; 2017).	It will comprise of schools, hospitals, an industrial facility, a port, a financial island, beach facilities, golf courses, and residential areas. It is anticipated that this ambitious project will be completed by 2035 (kaec.net, 2013; 2017).
<b>Riyadh Metro Service</b>	The metro network will have six lines in total, measuring 176 km in length, and 85 metro stations. It is planned that most of Line 1 will be based underground. In contrast, the majority of Line 2 will be built on a raised platform adjacent to a planned freeway (bechtel.com/Riyadh-Metro, 2016).	Three very different internationally based consortiums have been awarded design and construction contracts worth USD \$10 billion dollars each in order to design and build the Riyadh Metro network system (bechtel.com/Riyadh-Metro, 2016).	The Riyadh Metro network will form the backbone of Riyadh city's new public transport system. The metro network will also connect the densely populated residential areas to all public facilities, commercial, medical and educational institutions, as well as to the King Abdullah Financial District, Riyadh downtown, and connect the public transport center with the King Khalid International Airport. This massive project is expected to be completed in late 2018 (bechtel.com/Riyadh-Metro, 2016).
<b>An Expansion of Rail Services in the Kingdom of Saudi Arabia</b>	Across Saudi Arabia, the rail investment is part of the largest infrastructure project whereby the integrated network will consist of 19 railway lines which will cover 9,900km (sar.com.sa, 2017).	At a cost of USD \$8 billion dollars, this will be managed by the Ministry of Finance, while the investment will be financed by the Public Investment Fund (PIF) (spa.gov.sa, 2017).	The North-South line connecting the capital city Riyadh with Majmaah, Al Qassim, Hail, Al Jawf and the northern city of Al Qurayyat (sar.com.sa, 2017).  Two other Rail projects consist of a land-bridge project, connecting the eastern and western parts of Saudi Arabia; and the Haramain high-speed line, which will connect the cities of Makkah and Medina with the King Abdullah Economic City (KAEC) and Jeddah (spa.gov.sa, 2017).

(Source: adapted from: spa.gov.sa, 2017; kaec.net, 2013; 2017; sar.com.sa, 2017; Bechtel.com/Riyadh-Metro, 2016)

These projects therefore illustrate the need for modern day construction working practices by fully incorporating innovative technology in order to ease the working of all the construction

organisations and construction professionals that are involved, and to enhance their performance by assisting with scheduling, planning and construction management and after the completion of the projects in their entirety in the operations and maintenance phase of the project lifecycle.

These construction projects require resources from a wide variety of sources, both public and private. They are typically very expensive and attract public attention due to their impact on the environment, communities, and budgets. They transcend the discipline of engineering and require support from people of other backgrounds, including lawyers, politicians, scientists, and industrialists. These types of mega-projects introduce a whole new level of complexity not found with smaller scale engineering projects (Fiori and Kovaka, 2009), but they are required in Saudi Arabia as an incredible amount of new infrastructure is needed to support the country's burgeoning economy. There is also a continuing need for huge industrial development projects in the private sector. This is especially true as there is a need to diversify the nation's oil-based economy from the oil and petrochemicals industry, with high global energy demands increasing the need for Saudi Arabian investment in other sectors (Al-Tunisi, 2007). As such, these projects, such as the NEOM Mega City and King Abdullah Economic City, would enable Saudi Arabia to create additional value from its petroleum resources.

Furthermore, according to the research conducted by Al-mohawis *et al.* (2005), over the last decade the Saudi construction industry has contributed about 40 billion Saudi riyals to the national GDP, as well as employing approximately 14.4% of the total workforce in the country. With respect to the total national output, the GDP of the Saudi Arabian construction sector has been steadily increasing since the end of the 1990s (Al-ahli, 2004). The Five Year National Development Plans were designed to develop the kingdom's basic infrastructure. Through these detailed ambitious plans, it was aimed to develop the country's industrial, urban, religious and civic infrastructure (Al-thabt, 2013). At the end of each Five Year National Development Plan between 1980 and 2000, there was a contribution by the Saudi construction industry of between 30% to 40% of the non-oil productive sectors, as stated by Saudi Ministry of Economy and Planning (2009). Moreover, under Vision 2030, the government plans to increase the private construction sector's contribution from 40% of the country's GDP in 2015 to 65% by 2030 (spa.gov.sa). Therefore, during the last 60 years, Saudi Arabia has experienced an unprecedented construction boom due to its continued rapid growth. As a result of this boom the demand for the construction of new and upgraded

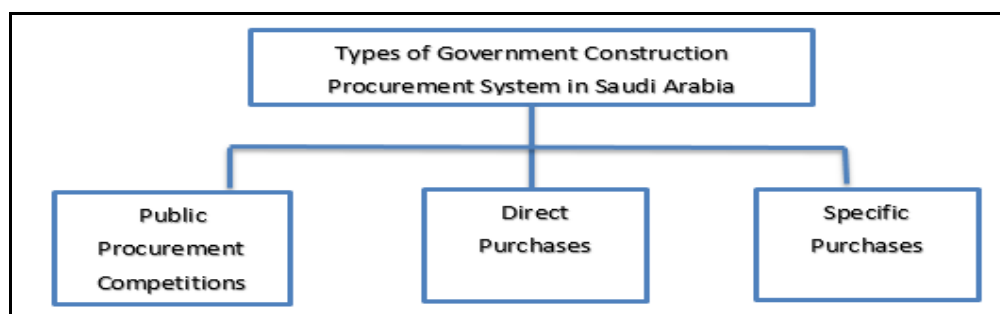


infrastructure throughout the kingdom. Hence as a result, the Saudi Arabian construction industry has been a major force in the development of the economy.

## **2.4. HOW CONSTRUCTION PROJECTS ARE CURRENTLY PROCURED IN THE KINGDOM OF SAUDI ARABIA**

The Government Tenders and Procurement (GTP) law in the Kingdom of Saudi Arabia was introduced by the central government in 2006, by Royal Decree M/58 of 1427 (2006). The government construction procurement system illustrates that there are three different types of procurement methods for government public sector construction projects in Saudi Arabia. These are known as Public Procurement Competitions, Direct Purchases and Specific Purchases.

The latter two procurement methods are for unique and special items only (Ministry of Finance 2006). Figure 2.2 below clearly illustrates the different types of government construction procurement system in Saudi Arabia.



**Figure 2.2: Different Types of Government Construction Procurement Systems in Saudi Arabia**

**(Source: adapted from the Saudi Ministry of Finance, 2017)**

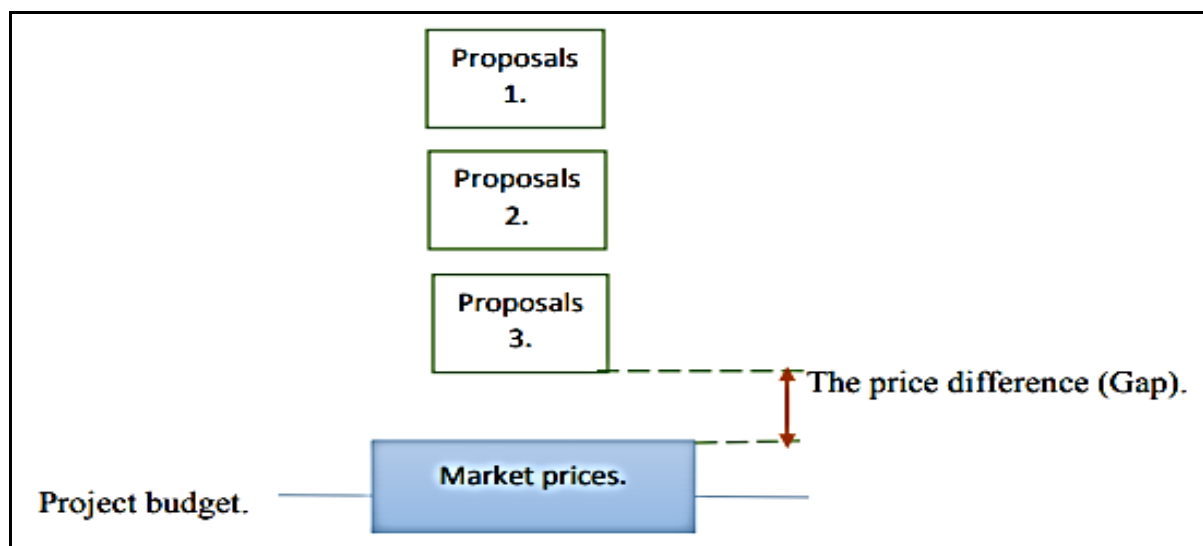
All works or services that need to be procured must be put out to public tender, unless exempted by the Procurement Law (Article 6). Both local and international companies interested in bidding on a government project are required to make themselves known to the specific government agency/ministry offering the project. This enables companies from the construction business to apply for involvement in building projects even if they are from outside the kingdom (Article 70) (Alofi *et al.*, 2016; Ministry of Finance 2006). When a construction project becomes available in the form of a tender, the government agency/ministry selects bidders from a list classified as prequalified/known companies and

invites them to bid for that particular project. The Saudi Government Tenders and Procurement Law (GTP) insists that all government bids are to be announced in the official Gazette (Arabic), in two local newspapers, and in the electronic media. After that, a competitive tendering process takes place among contractors which requires them to submit their tenders within a specific time. A direct head-to-head competition then occurs between the contractors, which drives the search for competent and innovative companies, making the client representative's job to appoint one of them extremely demanding (Al-Sedairy, 2001). The Ministry of Finance (2006) stipulates that the only language of communication is Arabic. Hence, all contracts, task schedules, determination of specifications, drawings, and all correspondence must be communicated in Arabic. The contractors rating is an indicator to determine the competency and capabilities of the contractor (financial, technical, managerial and operational capability). According to the tender regulations, preference is given to companies of Saudi origin which satisfy the requirements of the procurement and meet the national policy of encouraging national investment and enterprise. The law also specifies the method and process of competitive tendering selection on price and, therefore the number of competitors is usually narrowed down. Thus, by and large, the 'lowest price' or 'lowest construction cost' is the most usual criterion for appointment of contractors by project owners (Article 21) (Alofi *et al.*, 2016; Ministry of Finance 2006). The Saudi Arabian government does not allow contractors to win government projects unless they prove that the project corresponds to the capabilities of the contractor (Ministry of Municipal and Rural Affairs, 2010). However, in practice, the contractors are selected only based on the lowest price, so the majority of contractors are not qualified.

As a result, the common approach to procurement employed in the Saudi construction sector is the traditional design-bid-build (DBB) project delivery method. Idoro and Iyagba (2008) describe DBB as the method in which a project is separated into design and construction phases, which means that construction can start when the design is completed. Arain (2002) reported that conventional procurement practice in the Saudi construction industry does not involve the contractor in the design conceptual phase. Furthermore, other factors that affect the performance of Saudi Arabian public construction projects is the Saudi Arabian construction procurement system delivery method, which shows that the contractors have been selected only based on the lowest price. In addition, the majority of contractors who have been chosen are not qualified and are low performers (Alofi *et al.*, 2016). According to Al-bogamy *et al.* (2012), the major risk that affects project performance is the use of low

price bids in the Saudi government bidding system. Al-tolany (2013) states that the use of the Saudi Arabian procurement system causes many problems and delays in construction projects.

Similarly, Al-otaibi *et al.* (2013) identified the current procurement practice used in Saudi construction as one of the critical failure factors contributing to the under-achievement of a construction project's performance. Padhi and Mohapatra (2010) claimed that past work performance of contractors is not taken into consideration during the selection procedures, and thus the project will be delivered with poor quality because of the contractor's poor record of past work performance. Figure 2.3 below graphically illustrates the handling of construction proposals in the Saudi Arabian construction industry.



**Figure 2.3: Handling of Construction Proposals in the Saudi Arabian Construction Industry**

(Source: adapted from the Saudi Ministry of Finance, 2017)

Consequently, the current construction procurement methods generate much wastage of large expenditure on failed and incomplete projects, particularly with respect to factors such as time loss, delays, cost, quality, failure rate, re-tendering, and litigation cases. Hence the current practice of the tendering process is not efficient. The recent 2030 vision plan announced by the government of Saudi Arabia encourages all sectors to be creative, efficient, and environmentally responsible (Banawi, 2017). Technology such as Building Information Modelling (BIM) could help transform the construction industry in Saudi Arabia and improve

the final outcomes. Nevertheless, the use of BIM on public sector construction projects in Saudi Arabia has not been made mandatory by the Saudi Arabian government, neither has it been widely adopted by construction organisations within Saudi Arabia (Al-Hammadi, 2015).

## **2.5 PROBLEMS INHERENT IN THE SAUDI ARABIAN CONSTRUCTION INDUSTRY**

Construction projects in Saudi Arabia are often hampered by inherent risk and uncertainty, usually due to the varying project environment (Jadid, 2013). Therefore, the completion of the construction projects becomes challenging, as problems such as time overruns, delays, cost, quality and safety issues, changed orders and labour-related issues are common and often cause considerable losses. This situation is because of the nature of design and construction processes that consist of dynamic interactions amongst the different parameters such as the attributes of project, constraints regarding the site conditions, participant experience and cost (Lee *et al.*, 2006).

Henceforth one of the main factors involved for the exceptionally high rate of construction development and infrastructure projects in Saudi Arabia is the presence of vast areas of land, totalling approximately 2,260,000 square kilometres, while another factor is the adoption of policies achieving the necessary national development in a short span of time given the geographic, social and economic characteristics that have influenced the pace of socio-economic development within the Kingdom of Saudi Arabia (Al-thabt, 2013), such as supporting the new lifestyle and welfare standards adopted by the kingdom as well as the increasing rate of the country's population. The population in Saudi Arabia increased from around 7 million in 1974 to more than 25 million in 2009 (Ministry of Economy and Planning, 2009). Consequently, a large number of infrastructure projects have been required in order to fill the gaps where the infrastructure was lacking, according to the ambitious national development plans to modernize the kingdom (Al-Sobieh *et al.*, 2005).

It was the Seventh Development Plan (2000-2004) that resulted in the initiation of large-scale privatisation programmes by the government in which fully private construction projects were established and many Public-Private Partnerships were formed (Ministry of Economy and Planning, 2009). Within this period, new commercial banks were introduced, and major privatisation schemes were initiated. As such, there was a change in government strategy due to constraints in budget and the increases in infrastructure demands. Hence for these reasons

a major share of investment or funding responsibility was given to private investors (Molnar, 2003).

The Seventh Development Plan (2000-2004) also proposed mechanisms to be adopted for achieving project funding which included the involvement of foreign investors and the setting up of Public-Private Partnerships. All the characteristics of Private Finance Initiatives (PFI) (such as innovative design, performance quality, transfer of risk, sustainability, application of life-cycle cost, efficiency in accountability, monitoring, management and operation of infrastructures services) when taken as a whole make PFI a significant procurement system to serve as a tool to develop the Saudi construction industry through innovative improvement processes (Al-Saudi, 2011).

In particular, the objectives of Saudi Arabian public clients are to obtain a high-quality construction project through quality contract documents and quality construction. During the construction boom in the early 1980s in Saudi Arabia, quantity and speed were essential needs then, but currently time, cost and quality are much more important (Al-sapan *et al.*, 2012; Bubshait, 1992). Hence, the Ministry of Economy and Planning is now increasingly focusing on these three as the most important construction project objectives to be achieved (Al-sapan *et al.*, 2012).

Nevertheless, there are also many challenges in relation to the measurement and evaluation of the performance of the construction projects in the public and private sectors of the Saudi Arabian construction industry (Al-Otaibi and Price, 2009). Thus, according to Mitra and Tan (2013), these problems are integral and characteristic of construction projects in Saudi Arabia because of ineffective planning, changes in design, poor approval control, shortage of labour (in particular, the lack of a skilled workforce), lack of control by project managers, owner payment delays, and inadequate levels of productivity, as well as cash flow problems. Furthermore, according to the report by the Middle East Economic Digest, MEED (2005), there has been a severe shortage in the availability of contractors, consultants, engineers and skilled labour for handling the huge construction boom in the Kingdom of Saudi Arabia. As a result of these shortages, many construction projects were overseen by international consulting and construction organisations who began to operate in Saudi Arabia, as the tendering of Saudi construction projects was being done internationally. Consequently, due to the low availability of local workers, multinational construction companies and foreign workers filled the gap in this high demand in the Saudi construction industry (Al-Shaikh and Chahine, 2010). This in turn led to the shortage of labour in the Saudi construction industry

being eliminated by the influx of foreign workers. However, the working practices and methods of conducting business and use of technology of all the multinational construction companies, international consulting and construction organisations were disparate and varied greatly. Large discrepancies were due to differences in the backgrounds of the construction organisations, as well as their business culture, quality measures and management techniques (Mohammed, 2007; Al-Sobieh *et al.*, 2005). Accordingly, problems were raised relating to project design, procurement, health and safety, quality management and an increase in construction risks and delays, which then tended to increase the overall construction costs. These operational factors complicated matters and added uncertainties to the planning, design, construction and reliability of the Saudi construction industry (Al-Otaibi and Price, 2009). Successively, the phenomenal boom in construction projects and the required demand for their faster completion became challenges for the Saudi Arabian construction industry (Al-Sobieh *et al.*, 2005; Jaweed 2004; Al-Khalil and Al-Ghafly 1999; Amjad 1998; Assaf *et al.*, 1995; Ubaid, 1991; Al-Sultan 1987).

Generally, the problems faced by the construction industry differ from one project to another, depending on the attributes of the construction project (Al-Barrak, 2004). However, the majority of public construction projects have faced problems in Saudi Arabia, and 30% of all these projects have failed to be completed on time (Sambasivan and Soon, 2006). Al-Suliman *et al.* (2012) give examples of poor performance in the Saudi Arabian construction industry. Al-Barrak (2004) reports that insufficient and ineffective planning and scheduling is the major cause of delay in construction activities in Saudi Arabia as a result of which there may be problems in management, an increase in cost, impediments in the execution of the construction work and lack of coordination between the team members (Jacobson and Choi, 2008). According to the findings of Assaf and Al-Hejji (2006), approximately 70% of large construction projects in Saudi Arabia have suffered from time overruns. Based on their findings from project clients, they stated that the main causes of construction delay in Saudi Arabia included lack of labour and skills, design errors, and the slow progress of contractors. Assaf and Al-Hejji (2006) and Al-Kharashi and Skimore (2009), subsequently went on to state that the client, consultant and contractor are the main contributory parties to the execution of a construction project and many causes of critical delays in construction projects can be linked to them.

Moreover, a research study on the Saudi Arabian construction industry by Al-zara *et al.*, (2016) has established that the problems which challenge the performance of construction

projects are due to several causes such as financial issues, procurement, incompetent teamwork, lack of site management and supervision, and insufficient contract standardization. These problems have been summarized in Table 2.2 below.

**Table 2.2: Construction Performance Problems in The Kingdom of Saudi Arabia**

<b>Grouping of Problems</b>	<b>Factors</b>
<b>Inadequate contract, insufficient standardisation and specification</b>	Unsuitable criteria and processes for pre-selection of contractors, indefinite labour skills in contract, inadequate penalty clause in the contract, lack of speed in contractor performance and owner approval, insufficient accuracy in specification and standards.
<b>Financial issues</b>	Inadequate cost indexes used by owners for estimation of cost, lack of accurate cost estimation by contractors, unnecessary loading on the contractor, inadequate labourer food support by the contractor, lack of good performance by labourers, unsuitable schedule of payment, lack of budget from owners, insufficient information between owner's building and financial departments.
<b>Lack of site management and supervision</b>	Underrated leadership and supervision skills, inadequate communication between supervisor and contractor, insufficient direct supervision by owner, and inadequate direct supervision by the contractor.
<b>Unqualified teamwork</b>	Ineffective communication between contractor, owner and teamwork, illiterate labourers, overrated capabilities of teamwork from contractor, inadequate knowledge by contractor of local climate and environmental factors, inadequate training programmes for team, insufficient team encouragement, lack of team loyalty, dispute between owner and contractor over team abilities, lack of team accommodation on work site, unsuitable choice of teamwork and labourers by contractor, lack of knowledge of teamwork with modern technology.

(Source: adapted from Alzara *et al.*, 2016; Al-Hammad, 1995)

Furthermore, Al-Hammadi and Nawab (2016) and Jadid (2013) attribute ineffective and poor performance of the Saudi Arabian construction industry into managerial, expansion, financial and environmental factors. Haponava and Al-Jibouri (2009) have suggested that there is a lack of available techniques or mechanisms to be used for monitoring and controlling projects, as in the case of Saudi Arabia, and that even though some improvements have been made over the last decade, ineffective planning and lack of consideration of construction

projects during the pre-implementation stage, as well as failure during the execution of projects, are still significant challenges faced by on-going construction projects within the country (Haponava and Al-Jibouri, 2009; Al-Hammad, 1995).

## **2.6 COLLABORATION AND INTEGRATION IN THE SAUDI ARABIAN CONSTRUCTION INDUSTRY**

From a construction perspective, integration normally refers to collaborative working practices, methods and behaviours that promote an environment where information is freely exchanged among the construction parties (Baiden and Price, 2011). Integration and collaboration in the construction industry are known to improve productivity and efficiency in this industry as well as improving project delivery team performance (Shen *et al.*, 2015; Egan, 2002). According to an industrial survey carried out on the Canadian construction IT industry by Froese *et al.*, (2010), “the most frequently identified issue is related to collaboration which includes communications, document management, and interoperability.” From the same survey, on a question related to “the trends in information technology that will be important for the construction industry over the next 10 years”, the strongest response was for “Web-based collaboration and project management systems” (67%), followed by “integration of software tools across the project lifecycle” (43%) (Froese *et al.*, 2010, p819).

Due to the complexity of the construction industry, the multiple phases of the construction project life-cycle, and the involvement of multidisciplinary teams, integration becomes an important and imperative step to achieve efficient and effective collaboration (Ibrahim *et al.*, 2011). Therefore, this calls for interoperability within the construction industry as a whole. However, interoperability problems in the construction industry stem from the highly fragmented nature of the industry and are further compounded by the large number of small companies that have not yet adopted advanced information and communication technologies (Gallaher *et al.*, 2014).

With the rapid advancement of information and communication technologies, particularly Internet and Web-based technologies over the last 20 years, various types of systems integration and collaboration technologies have been developed (Shen *et al.*, 2015). Nevertheless, it is only recently that the construction industry has started to adopt software systems that support and promote the concepts of integration and interoperability (Halfawy and Froese, 2017), yet it is still lagging behind other sectors such as the manufacturing industry.



Furthermore, nowadays is seen as the time for the Saudi Arabian construction industry to embrace new ways of working if it is to continue to be competitive and meet the needs for its infrastructure demands (Banawi, 2013). Collaborative working within this industry is considered to be essential if construction project management teams are to consider the whole lifecycle of the construction process (Al Najem *et al.*, 2012). Much of the work undertaken in the Saudi construction industry on collaborative working has focused on computer-aided design, and knowledge management alone (Alrashed *et al.*, 2014).

Yet in reality, within the Saudi Arabian construction industry there is a need for the uptake of collaborative technologies, in which everyone involved in a construction project has access to the same information (Banawi, 2013). The owner, the project team, design consultants, general contractors and subcontractors can work together to ensure real-time information exchange, resulting in effective decision-making and increased ability to deliver projects on time and within budget. Since this is generally not the case, it is not uncommon to see Saudi Arabian construction organisations still relying largely on paper-based processes (Sodangi *et al.*, 2016).

Consequently, the fragmented and adversarial nature of the Saudi Arabian industry is limiting the potential for integrated construction project teams with open communication and information exchange (Banawi, 2013). As sharing information is viewed as a key indicator of team integration practice, the challenge is to ensure that the correct construction information reaches the appropriate person at the right time for construction projects in Saudi Arabia (Alshawhi and Faraj, 2012). Thus, integration and collaboration are considered vital to the process of project delivery in construction and in achieving maximum value. Yet, despite advances in technology with the use of web collaboration tools, the level of integration amongst stakeholders is low, which limits the ability to add value in the early stages to projects in the Saudi Arabian construction industry (Sodangi *et al.*, 2016; Alrashed *et al.*, 2014; Banawi, 2013).

## **2.7 THE USE OF COMPUTER-BASED TECHNOLOGY IN THE SAUDI ARABIAN CONSTRUCTION INDUSTRY**

The IT revolution of the 21st century has led to the evolution in computer science and information technology, which is changing the work process of most industries (Chan, 2014). The use of IT in construction is now a necessity. Most construction processes now rely on IT systems and tools to design, plan, inform, and communicate information and processes

(Sarshar and Connolly 2013). The benefits attainable with IT, such as improved communication, efficiency, quality and competitive advantage, are undeniable and cannot be over-emphasized (Lautanala *et al.*, 2013).

Anumba *et al.*, (2008), state that construction is an information intensive industry, and the adoption of information and communication technologies (ICT) with regard to information delivery is the key to better management and implementation of construction projects. This is consistent with Al-Maatouk and Othman (2017) who emphasize that there is now a global realisation of how important it is to implement and integrate information technology in the construction process in order to reduce cost and achieve more efficient projects, since this allows for specific project objectives to be achieved, such as determined project time, allocated cost, quality and safety of the construction projects, integrated data exchange, cost savings, efficient and effective decision-making, and achievement of better competitive advantages within the construction industry (Abedi *et al.*, 2014). Consequently, information technology (IT) is a significant tool for supporting the construction industry with the required coordination and effective communication in addition to creative and intelligent ways of collaborating (Lang *et al.*, 2012).

Al-Maatouk and Othman (2017) go on to state that the adoption of ICT creates the potential of a best practice model for increased collaboration between construction project teams because all the project team members and stakeholders are styled into a common way of working. As well as creating the opportunity to simplify and streamline communication and interdepartmental coordination, new modes of teamwork are supported and in many instances total process re-engineering within the construction organisation is achieved. Hence it would be accurate to describe the adoption and utilisation of ICT as essential for effective collaboration in the construction industry, as it reduces the time required for data processing and information sharing. It also improves the overall project operations through communicating the relevant information, which results in effective coordination and decision-making (Underwood and Khosrowshahi, 2012).

The adoption of computer-based technologies in the Saudi Arabian construction industry has been slow in aiding and reinforcing the processes of design and construction. There is also a lack of any research studies or official statistics on the effective use of computer and Information Technology usage in the construction industry of Saudi Arabia (Shash and Al-Amir, 1997; O'Brien and Al-Biqami, 1999).

Since Information technology (IT) can play a crucial role in dealing with the challenges of construction projects, Sidawi and Al-Sudairi (2014) have illustrated the importance of using technological advancements in computer and IT technologies in order to improve the performance of construction projects in Saudi Arabia. Sidawi and Al-Sudairi (2014) go on further to emphasize that nowadays almost all Saudi Arabian construction organisations are well advanced with regard to the use of computers and ICT technology and have a more realistic understanding of the impact that Information Technology has on the construction industry.

Yet despite the fast developments in IT and the creation of many IT applications for the construction industry, some issues still hinder the applicability of these systems in the Saudi construction industry. For instance, there is a problem with regard to the diffusion of IT in the construction industry and the absorption of IT into work practices. This includes the level of strategic IT investment by construction industry firms (Al-shawi *et al.*, 2009). Other barriers include IT technical shortages, deployment of the system on an ad hoc basis, isolated project management practices, and costly systems (Sidawi and Al-Omairi, 2010).

The advancement in computers and information technology used in business and by lay individuals has significantly changed the world. Computer Aided Design (CAD), the Internet and the World Wide Web (WWW), Email and Electronic Data Interchange (EDI), Web-based Project Management Systems (WPMS) and hand held mobile systems which incorporate mobile tools, personal digital assistants (PDAs), wireless tools, 3D virtual reality and other technologies have brought significant changes into the construction industry, and construction organisations are now assessing how to avail themselves of the benefits these offer (Sidawi *et al.*, 2013; Al-sahli, 2011).

Additionally, Computer Aided Design (CAD) is the conventional computer software tool supporting the solution to construction design problems. The use of complex 3D modelling and coloured graphics in CAD tools in the mid-1990s has improved Saudi Arabian construction organisations (Jadid and Idrees, 2007). Prior to the introduction of CAD, all aspects of building design in Saudi construction organisations were carried out manually by two-dimensional (2D) hand-drafted drawings which were mostly referred to as traditional drawing practices (Al-rashed *et al.*, 2014; Al-sahli, 2011). Since then, the positive effects of CAD have been seen, as it has influenced the education sector, construction-related research, the discipline of architecture, and professional construction working practices in Saudi Arabia

(Sarshar and Connolly 2013; Al-shawi *et al.*, 2009). The usage of CAD has become a component of computer-based technology within the construction industry and architectural organisations in the country. As a result, universities and colleges have also contributed to the preparation of a workforce that is skilled in using and operating CAD in the construction industry of Saudi Arabia (Al-rashed *et al.*, 2014; Al-sahli, 2011).

There have been rapid developments in computing technologies and the invention of many IT software applications specifically for the construction industry, such as project planning software which includes Primavera, Microsoft Project, GEST, ICON and JobMaster. CAD applications are of varying types: examples include AutoCAD, ArchiCAD, MiniCAD and FastCAD (Al-sahli, 2011), while Snape PLT/Vector software, Vector, RIPAC, CATO, WinQs, CatoPro, MasterBill, QS Elite, Snape Vector and FBS-Estimator, Esti-Mate and PRESTO are just some of the Quantity Surveying dedicated software available. However unfortunately, these technologies have not been used to their full potential, for construction project management purposes in the Saudi Arabian construction industry (Sarshar and Connolly 2013; Al-shawi *et al.*, 2009). This highlights the challenges in relation to the adoption of computer-based technologies and diffusion of ICT into the working practices of the Saudi construction industry (Al-Otaibi, 2011). As such, the Saudi Arabian construction industry should incorporate a strategic level of investment in IT (Al-rashed *et al.*, 2014).

The justification of IT investments is one that construction organisations are confronted with if the IT applications are available. According to Sarshar and Connolly (2013), the construction industry is yet to make a positive shift, partly due to under-investment in IT developments, the complex nature of information formats and the supply chain arrangements within the industry. Lautanala *et al.*, (2013), undertook a research in Finland to analyse the maturity of capability of the use of IT in the Finnish construction industry and documented its respective benefits and cost. At the end of their research, they found that an increase in investment in IT brought about a proportionate increase in benefits over time. Taking these findings into consideration, consequently if Saudi Arabian construction organisations were to undertake investment in IT they would be able to reap the benefits of the technology immediately as well as gain benefits created from such an investment in terms of increased profit.

Furthermore, one of the main forms of ICT to emerge as a novel way of working in the construction industry is Building Information Modelling (BIM), which is represented as the

practical application of information management in terms of technology and process (Tardif, 2015; Reddy, 2012; Eastman, 2011). The introduction of Building Information Modelling (BIM) has led to collaborative working processes in construction project work that involves integrating the various disciplines, thereby increasing efficiency and effectiveness (Succar 2009). BIM technology allows for the creation of intelligent building information models, and this has improved the visualisation, coordination and management of project life-cycle information in the construction industry (Singh *et al.*, 2011). The process allows the project team to work effectively, particularly when identifying potential problems before they start to build on site (Porwal and Hewage 2013).

MacLeamy (2012) and the UK BIM TaskGroup (2013) define BIM as a collaborative way of working, underpinned by digital technologies which unlock more efficient methods of designing, creating and maintaining construction assets. The BIM model, which is a data-rich, object-oriented parametric representation of the facility, will serve as a repository for data which can be extracted and analysed to suit all the different users' needs throughout the entire lifecycle of the building (Azhar *et al.*, 2012). As such it serves as a collaborative platform for all stakeholders to share their knowledge resources and information. Sufficient information increases communication effectiveness, while effective communication allows stakeholders to exchange accurate, up to date and clarified information in order for decision makers to form reliable decisions.

AIA (2007) has further identified that BIM is a shared digital representation founded on open standards for interoperability. Therefore, BIM demands collaboration as it involves a collaborative process and technology.

Hence the collaborative process is one of the key factors for BIM success. The construction industry has embraced BIM as a technological, cultural and philosophical concept, reaping the benefits such as time and money savings through reduced rework, and enhanced understanding of a project through visualisation and collaboration, thereby promoting efficiency in the management processes (SmartMarket Report BIM, 2009).

Moreover, the next chapter of this thesis further discusses the associated literature regarding Building Information Modelling (BIM) in order to explore, appraise and define the concept, and provides information on BIM for the construction industry as a whole and in particular the Saudi Arabian construction industry, in terms of its use, requirements and benefits.

## **2.8 SUMMARY OF CHAPTER TWO**

Due to the high demand for infrastructure projects and their large sizes, a great number of construction opportunities have materialized in the construction market of Saudi Arabia. However, most of the country's indigenous construction companies lack the knowledge and management experience of delivering large construction projects, and thus many foreign construction companies in partnership with local companies deliver projects in the Kingdom of Saudi Arabia. Although continuing investment is provided by the Saudi Arabian government for the development of the Saudi construction industry, there are many challenges arising in the construction project environment due to inherent problems with the delivery of the project. These problems usually occur because the criteria for success, such as cost, quality, and time, are lacking. The absence of such criteria is due to different kinds of factors that include financial difficulties, changes in orders, delayed decisions, obstacles and delays in receiving work permits, and inefficient communication between the project team members.

Just as the types of construction projects vary, correspondingly the project designs change and become modernized. Demands for advanced engineering skills and specialized materials, along with new and improved construction equipment, and sustainability, are increasing too. The Saudi Arabian construction industry has been experiencing such extraordinary growth that it has encouraged further investment into its construction industry. Nevertheless, the Saudi Arabian construction industry has been slow in adopting new and innovative computer based technologies.

Nowadays the advent of computer-based Information Communication Technology (ICT) has turned out to be vital to the working practices of construction organisations as well as the construction industry in general because it has eliminated many of the inefficiencies that the industry has endured as well as improving the productivity of the design process. As a consequence, this places great importance and emphasis on the integration and use of computer-based technological advancements such as Building Information Modelling (BIM). Consequently, Chapter Three will discuss Building Information Modelling (BIM) in detail.

# **CHAPTER THREE**

## **BUILDING INFORMATION MODELLING (BIM) IN THE CONSTRUCTION INDUSTRY AND KSA**

### **3.1 INTRODUCTION TO CHAPTER THREE**

This chapter presents an introduction to Building Information Modelling (BIM) as part of a comprehensive literature review. It goes on to discuss the basic concepts of BIM in the construction industry along with a digital illustration and representation of BIM and the evolution of its different stages. The chapter also presents a review of studies on how BIM is used in countries across the globe, with a particular focus on BIM in the Saudi Arabian construction industry. This chapter also reviews the benefits of BIM as well as the barriers to its adoption in the construction industry, and the challenges of implementing it in the Kingdom of Saudi Arabia.

### **3.2 BUILDING INFORMATION MODELLING**

The emergence of Building Information Modelling (BIM) is the latest advancement in computer and information technology for the construction industry and is an excellent tool for the exchange of knowledge and information between the various disparate construction project disciplines so that there is an effective coordination and integration of the different phases of the project lifecycle. Hence, Building Information Modelling, commonly known as BIM, is an integrated digital representation that incorporates all the practical and corporal features of the competences of construction planning technology to address some of the challenges currently faced by the construction industry (Butkovic and Heesom 2017; Underwood and Isikdag, 2010).

BIM has been regarded as an information technology which helps the construction designer with archetype design and simulations of the project. Moreover, with the help of BIM, recovery, access and maintenance of the information becomes easier than when traditional methods are used (Singh *et al.*, 1010). According to Arayici, *et al.*, (2012), through use of BIM technology, construction industry issues can be addressed and many advantages can be achieved, such as cost reduction, greater efficiency, better quality, increased productivity, improved lead times and avoidance of duplication using effective communication with stakeholders in construction projects. Thus, IT helps in the management of the complexity of

projects in the field of construction. As a result, it also helps in achieving the objectives of a project through saving time and cost, and improving quality and scope. Besides this, long-lasting sustainable measures and practices would assist in maintaining the quality of the project, by eliminating waste and minimising cost. Similarly, according to BuildingSMART (2012), BIM can be defined as a tool which can be used to plan, design, simulate, implement and maintain the project data from the initial planning stage to the project execution one. In broader terms, BIM can be defined as an integrated process which supports the reprocessing and storing of data, statistics and knowledge throughout the development of a construction process (Vanlande *et al.*, 2008).

Galiano-Garrigos (2017), further states the main purpose of the use of BIM in the construction industry is to improve the interoperability and association among the stakeholders of the competences of the construction process. Again, BIM enables the construction industry stakeholders to use a database infrastructure so that all the design and building competences can be encompassed with respect to the different perspectives of the stakeholders (Arayici *et al.*, 2012). One of the key advantages of this technology is that it offers a collaborative system. Moreover, BuildingSMART (2012) refers to BIM as a multi-disciplinary framework which enables collaboration among the stakeholders in bringing out the best quality design while optimizing the costs and minimizing the time of the project.

### **3.2.1 The Origins and History of BIM**

Over the past 20 years, BIM has been a universal technology that has been extensively used in the construction industry around the world (Quirk, 2012). Considering the ubiquitous presence of this term, therefore, it is important to have some knowledge of the history of BIM in the construction industry in order to understand the invention of this perfect architectural software package that has transformed the way of drafting and designing architecture by replacing conventional 2D CAD works (Garber, 2014).

The history of creating this process and technological solution for the construction industry is complicated and the result of a great deal of effort by various players from North America and Western Europe. The conceptualisation of this process and technological innovation was fortified by Douglas C. Englebart, who in 1962 provided a mysterious vision of the future of the construction industry (Wu *et al.*, 2017). At that time, Englebart predicted that parametric manipulation, object-based design, and relational databases for architectural and building design would become a reality in the future. The following year, Ivan Sutherland developed a

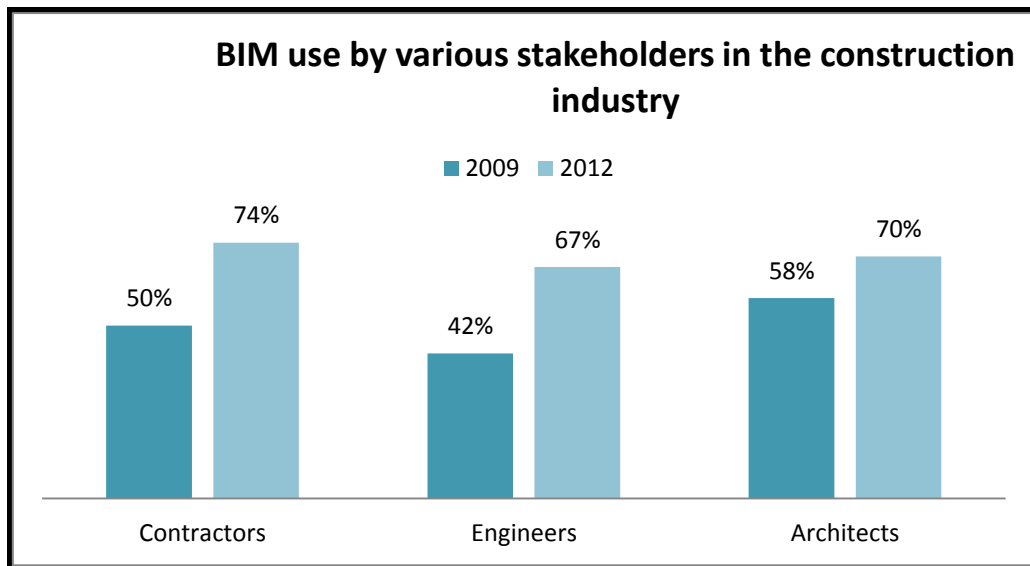


‘Sketchpad program’ which allowed automated visualisation of the geometric representation of a building design (Sutherland, 2003).

In this regard, two different methods, known as constructive solid geometry and boundary representation, were invented to enable the designers to visualize and represent their design outcomes. The Building Description System (BDS), developed by Charles Eastman in 1970, was considered to be the very first project leading towards the introduction of BIM (Latiffi *et al.*, 2015). This project was developed in order to describe library elements and added to a model. Eastman believed that BDS would be helpful for the construction industry professionals as it would reduce the costs of drafting and design and would enhance the effectiveness of the process by more than 50% (Eastman, 1976). Again, in 1977 Eastman developed another project, called GLIDE, which is regarded as exhibiting most of the key features of today’s BIM software solutions (Goubau, 2017).

Later, in 2002, a White Paper entitled ‘Building Information Modelling’ was introduced by Autodesk, and other market players such as Bentley Systems and Graphisoft followed in the footsteps of Autodesk to become involved in similar types of projects (Autodesk, 2002). On the other hand, Martens and Peter (2004) argued that ArchiCAD, which was introduced in 1987, was considered to be the very first implementation of today’s BIM software because it offered the first ever CAD software that could be installed and used on a personal computer to make both 2D and 3D visual representations of the design. ArchiCAD was also the first to create BIM software solutions to install on personal computers (PC’s) (Martens and Peter (2004).

Since its invention, BIM has been introduced and used by different industry professionals such as construction engineers, civil and structural engineers and architects. BIM systems not only create 3D virtual models, but also facilitate the collaboration between stakeholders. The principal aim of BIM is the management of stakeholder input throughout the entire lifecycle of a project (Motawa and Almarshad, 2015). Figure 3.1 (below) reveals the use of BIM by various stakeholders of the construction industry and also shows the trends of BIM use throughout the years 2009-2012. It can be seen that contractors are the main users of BIM in the construction industry, followed by architects and then engineers. Again, according to the McGraw Hill Construction Report (2012), it has been found that usage of BIM by construction companies increased from 28% in 2007 to 49% in 2009, and further increased to 71% in 2012.



**Figure 3.1: Adoption and Use of BIM by Contractors, Engineers and Architects (Source: McGraw Hill Construction, 2012)**

Most of these organisations in the construction industry have already abandoned illustration-based CAD programming and have pushed ahead to apply BIM in the greater part of their construction project (Dastbaz *et al.*, 2015). The enormous change in the construction and building development industry is moving from an innovation based strategy to a 3D decipherable model, which allows the user to check the execution of the plan, as well as the development and working data (Eastman, 2011).

Crotty (2013) states that BIM is a key to the achievement component in innovation and it provides various specialized arrangements. The entry of BIM into the construction business is a creative change innovation that enables construction procedures to progress. The act of designing change, from 2D drawings to 3D digital models, opens up the opportunity to assemble the models in the same way as a building is constructed with the development of a 3D BIM model starting early in the development cycle (Butkovic and Heesom, 2017). BIM provides illustrations and perceptions for the construction project that for example allows for: how the contractual worker's prerequisites can be customized and assessed in the early planning stages; how the outline choices are considered in terms of vitality, structure, etc.; how designers and experts join in the venture procedures; and how the building will develop and work subsequent to being handed over (Abanda and Byers, 2016). BIM cleverly

influences these procedures and stages, and further enhances them by permitting other actions to take place and checking for errors in plans (Eastman, 2011).

With BIM innovation, an exact virtual model of a building can be carefully developed. The technology produces a visual model that contains the exact geometry and applicable information needed in order to assist the development, creation and acquirement exercises that are required so as to understand the project design during the planning phase of the construction (Eastman *et al.*, 2008). As is illustrated in Figure 3.2 below the 3D visualisation is the basic essential feature of BIM.

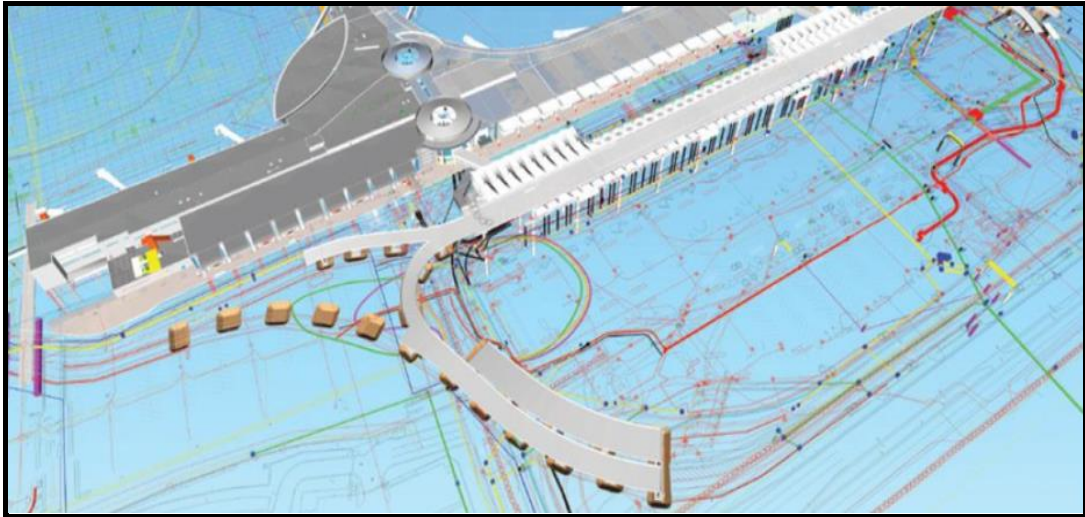


**Figure 3.2: Use of BIM by the Panama Canal Authority**

**(Source: McGraw Hill Construction, 2012)**

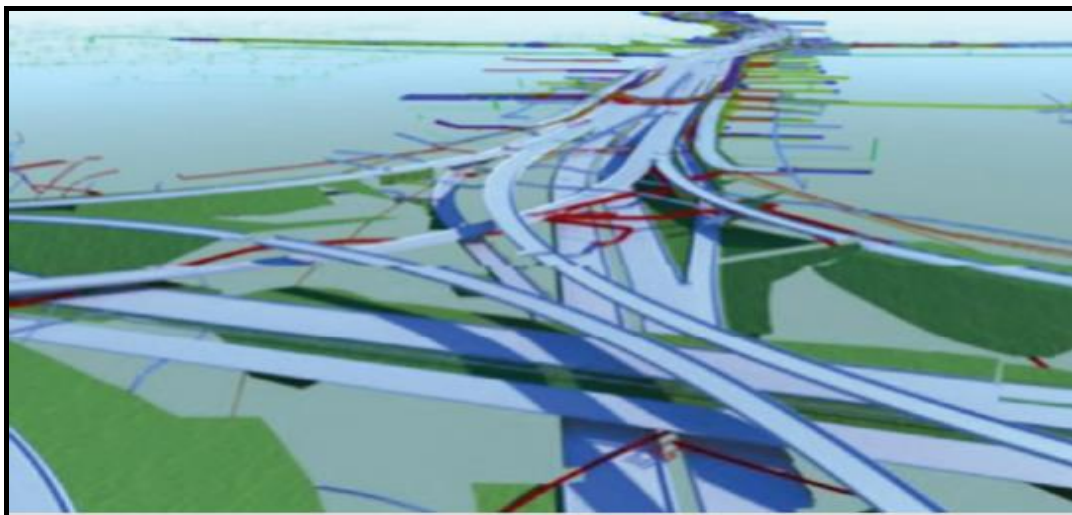
In the expansion project initiated by the Panama Canal Authority in 2007 (refer to Figure 3.2 above), BIM was adopted and implemented into the expansion project (McGraw Hill Construction, 2012). In this project, BIM was primarily implemented in the design phase of the project, while it was expected that BIM will be applied into other project tasks such as scheduling for the project.

The San Diego International Airport expansion project known as the Green Build involved the construction of new roadways, parking areas, aircraft gates, taxi lanes and runways that serve Terminal 2 as can be seen in Figure 3.3 below. Here all the construction works were coordinated with the use of BIM right through from the design to the construction phase (McGraw Hill Construction, 2012).



**Figure 3.3: Use of BIM at San Diego International Airport Project**  
 (Source: McGraw Hill Construction, 2012)

The Wisconsin Department of Transportation has ensured that BIM plays a key role in its road and highway projects to illustrate the physical features of road design, its associated drainage, existing road segments, lanes, curbs, and pavements, as well as slopes and elevations, bridges and columns, legal boundaries and rights-of-way as illustrated in Figure 3.4 below. This has been carried out to accurately simulate and analyse different aspects of project performance in order to maximize the Department's return on investment through its use of BIM (McGraw Hill Construction, 2012).

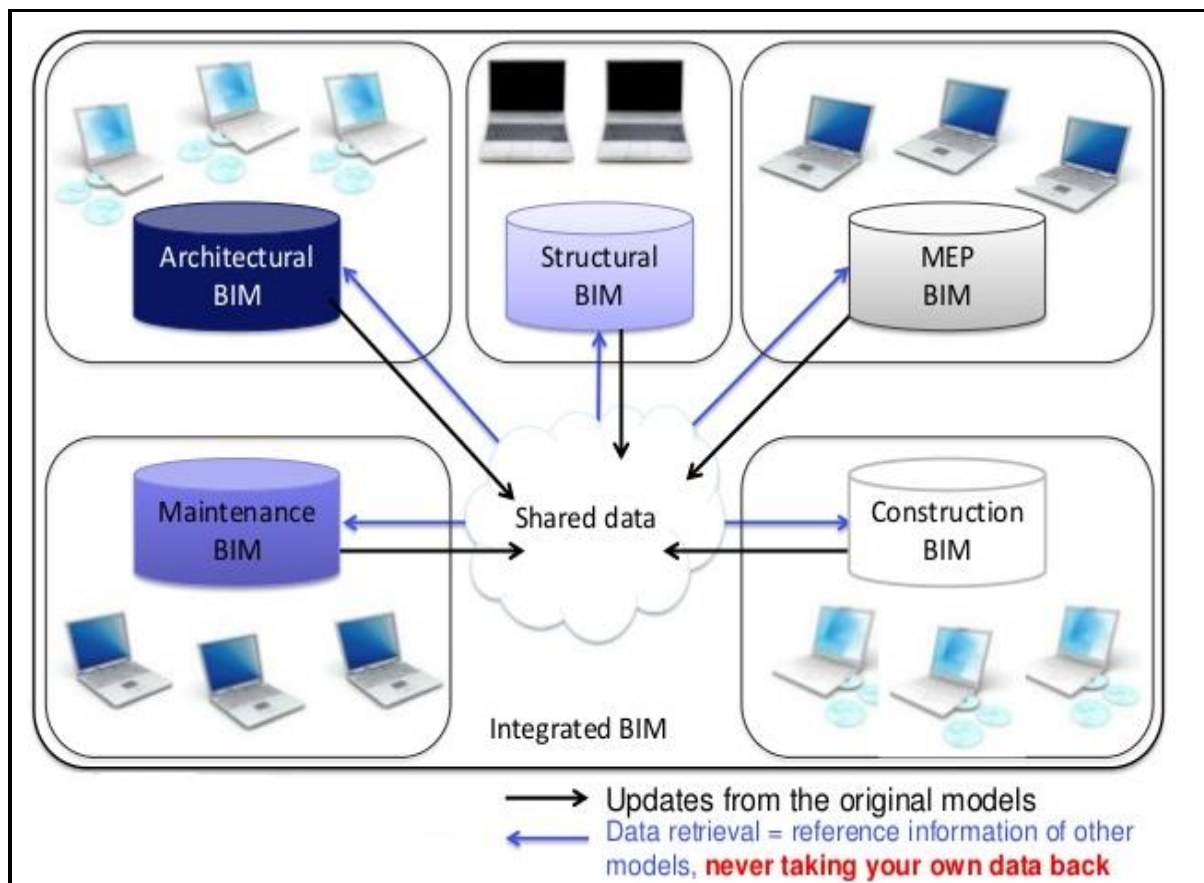


**Figure 3.4: Use of BIM on Road and Highway Projects**  
 (Source: McGraw Hill Construction, 2012)

However, BIM is not just 3D CAD (Crotty, 2016). In addition, it is more than delivering the project documentation in an electronic version (Galiano-Garrigos *et al.*, 2017). It is about information use, re-use, and exchange, of which the digital format is just one part. According to Eastman (1999), the use of BIM in construction projects at every stage of the construction life cycle (pre-design, feasibility study, design, construction planning, resource management, execution, and maintenance) can be seen as a holistic approach.

### 3.2.2 The Concept of BIM

BIM helps to discover any potential risks associated with a design at its early stage, which enables the designer to simulate and evaluate any major impact which may occur during the project execution stage. Building information modelling enables the designer to build a virtual building prior to the construction of a physical one (Smith and Tardif, 2009).



**Figure 3.5: Multiple Models That Can Be Implemented with BIM on a Single Project to Share Information / Data Between Domains**

(Source: Kiviniemi, 2015)



As indicated in the diagram above, BIM software is basically a database that is used for sharing information and the exchange of data for the various different types of activities to be carried out on construction projects as well as for various software applications required throughout the project lifecycle to achieve a BIM-based collaborative workflow (Kiviniemi, 2015). That information stored in the database can be used as needed throughout the construction process. Every input and shared piece of information from any third party 3D modelers, or contractor's staff (such as structural engineers, architects, or civil engineers), and subcontractor staff (for instance, electrical engineers, or drawing engineers) is very important in order to produce an amalgamated model which is then integrated into the BIM software. All these contractors and subcontractor staff are required to work using the BIM software rather than traditional paper-based documentation. As a result, with BIM a 3D representation can be obtained instead of a 2D one, and each of the members in the construction team can visualize their required information from the model developed by BIM. This collaborative workflow sets out the requirements for new processes and methods that could be adopted by all project stakeholders as an innovative way of working, as these new methods of collaborative work clearly illustrate the importance of IT to support this new workflow (Alazmeh *et al.*, 2017).

As mentioned earlier, BIM constructs a virtual building prior to the physical one. This virtual building can be defined as a model which can be tested and adjusted based on the design requirements for the physical building prior to the construction process (Kymmel, 2008). If any mistakes or problems are found in the virtual building, they will not cause any serious damage to the construction project, as they can be corrected and modified as required. In the case of this virtual building, all the aspects of the construction project are considered and integrated into the BIM software in order to avoid any discrepancies during the physical construction project. Elvin (2007) and Hardin (2008) mention that BIM can provide both 2D and 3D drawings and visual representation of the overall process of the construction project: for instance, it provides scope data, specifications, costs data, and the timeline of the project. In contrast, Kymmel (2008) postulates that BIM will represent drawings and visual representation with respect to the information provided and the model developed for the construction project. So it can be said that in order to benefit fully from BIM, all types of information considering various aspects of the construction project need to be provided. Kymmel (2008) lists some of the major information needed for BIM:

1. Information about the component: this is very basic information that provides graphical drawings and visual representation of the construction build.
2. Parametric information: this type of information consists of various parameters of an object. Most of this type of information consists of the area, volume, and density in order to achieve the actual geometry of the object based on its weight.
3. Linked information: this type of information is not an existing part of the model itself but is somehow associated with the model.
4. External information: this is generated from external sources and BIM is not concerned with such information. For example: specifications obtained from manufacturers about a product is external information.

The formation of an object-oriented database through the use of BIM has been identified by Elvin (2007). With the help of BIM, both qualitative and quantitative information about the object can be obtained, such as a representation of a window or a door or a wall. For example, in the case of a 2D drawing of a window, only the graphical representation of lines can be viewed, while with BIM, the graphical representation of the window will show all types of information regarding the object, such as the size of the window, the costs and scheduled time associated in making it, and even the manufacturer of the window. Another important aspect of BIM is the relational database, which means that any changes in a particular object within the design will change all other interrelated objects based on the change made. As for example, if a wall is deleted from a design then all of its associated doors and windows will be deleted automatically and all other data will be adjusted simultaneously. With the help of this BIM application, the construction process can be analysed in its very early stages, which permits the contractors to become involved in the design development phase of the project.

### **3.3 IMPLEMENTATION OF BIM**

BIM and its utilisation of the information has a central role to play with regards to meet the construction project objectives. Undoubtedly, there is change from 2D drawings to modelling. BIM can be used throughout the many phases of the construction project lifecycle for improved planning and coordination with consistent, transferable, information rich data which can be used by all members of the project team for analysis and visualization purposes. Subsequently the use of BIM in many phases of the construction projects are discussed further.

### **3.3.1 The Use of BIM in the Planning Phase of a Construction Project**

In a construction project, the planning stage is crucial, as it incorporates every aspect of the project, such as purpose, objectives, available resources, allocated budget, project deliverables, and scheduled time to complete the project. A successful execution of this planning stage indicates that the project can be completed on time by using the allocated budget for the project. Pierce (2013) mentions the following activities as being associated with the planning stage of a construction project: -

1. Planning for work: construction projects are normally divided into several parts which need to be completed in a logical order based on the priority and interdependence of different activities.
2. Scheduling for work: within the schedule of the construction project, the estimated time for the completion of each and every activity need to be included.
3. Scheduling for materials, labour, and equipment: all the resources which will be required during the activities of the construction project need to be scheduled and evaluated.
4. Project budgeting and cash flow estimation: with the help of project budgeting, the total costs of the project can be estimated and allocated.

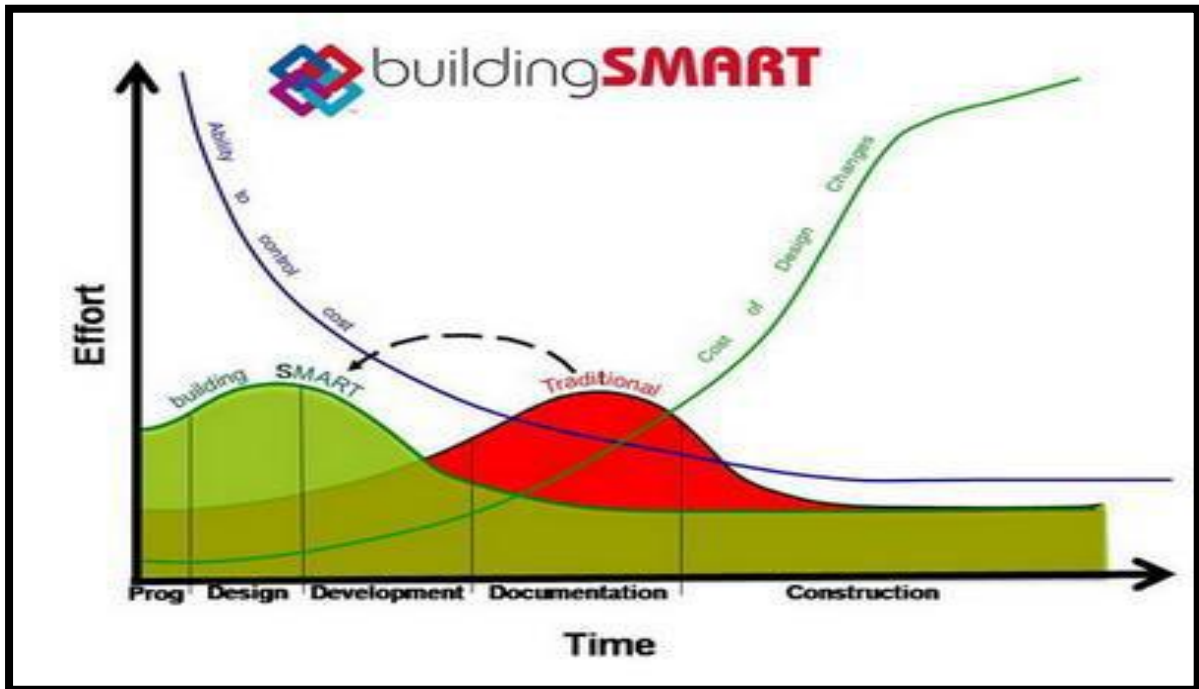
It is clear from the above discussion that the project planning stage integrates all the information regarding budget, timeline, scheduling of works, and delivery date of the project, in full. Project planning integrates the time, costs, and quality of the project and is essential for the overall quality of the project management.

Eastman *et al.*, (2008) emphasize the importance of the planning phase of the construction project, as most of the information needed for further stages is gathered and accumulated at this one. All of this information is collected from the contractor's staff and subcontractors during the planning phase of a project, and then integrated and included into the BIM software.

The MacLeamy Curve promotes a workflow where the decision making process is moved further forward and lowers the cost of refining design (Eastman *et al.*, 2008). From the MacLeamy Curve diagram in Figure 3.6 below it can be observed that the further you are



through the design process, the higher the cost of design change. This is also known as the concept of shifting the effort. This also has a direct correlation with potential project delays, wastage and increased delivery costs (Aranda-Mena *et al.*, 2009).



**Figure 3.6: The MacLeamy Curve For Time - Effort Distribution**

(Source: Eastman *et al.*, 2008)

From the above Figure 3.6, it can be seen that throughout the planning phase, the capacity to control the costs and practical skills is a priority. This is highlighted by Smith and Tardif (2009), who state that nearly 80% of the overall construction costs can be evaluated during the first quarter of the planning stage. On the other hand, with the help of BIM, a better design solution can be obtained as the topmost level of planning work can be relocated back with the costs changes and the capacity to control the costs. This can be justified through the nature of BIM implementation. The implementation requires a high and long-term investment, and the return on investment (ROI) can only be justified over a succession of project executions which also involve continuing efforts from the construction company. Again, Smith and Tardif (2007) and Aranda-Mena *et al.*, (2009) indicate that the overall costs of BIM implementation usually come from the training costs, costs of hardware and software implementation, and process flow modification.

Based on the level of information development through the planning stage of the construction project, Eastman *et al.*, (2008) divided the BIM process into four categories, as follows:

1. Addressing the conceptual design: at this level the required information is for the generation of a basic building plan which includes the appearance of the building, its position and orientation, and its structure.
2. Addressing the use of BIM for in-depth design and analysis of the building project: at this level, information is required to determine the variations within the parametric information of the building system.
3. Addressing the use of BIM for the development of construction level information: this level of information is needed to produce standardized construction paper-based documents.
4. Addressing initial information for fabrication level modelling: at this level, information is required for use directly in the construction phase of the project.

Subsequently, Table 3.1 below summarizes the use of BIM during the planning phase of the construction project:

**Table 3.1: Use of BIM Within the Planning Phase**

Point View	BIM Use
Conceptual Planning	Massing and sketching Space planning Environmental Analysis Site development
Design and Analysis	Structural Analysis Energy Analysis Mechanical Equipment Simulation Lighting Analysis Acoustic Analysis Air Flow/CFD Building Function Analysis/Clash Detection Cost Estimation Improving Building Performance Experimental Design Option
Construction level Documentation	Building System Layout Drawing and document production Specification Bill of quantity
Construction	Collaboration between design and construction Early identification of long lead-time item and shortening procurement schedule Value engineering Constructability analysis Construction Sequencing/4D analysis 5D analysis

(Source: adapted from: Kymmell, 2008; Smith and Tardif, 2009; Eastman *et al.*, 2011)

### 3.3.2 The Use of BIM in the Design Phase

The early phases of any construction and architectural design follow a recurrent process in order to transform the knowledge base of the design phase to design solutions for the construction or architectural project (Al-husban, 2012). This process follows the guidelines and requirements of the design problem, requirements from the projects, and the expected or projected limitations of the architectural projects. According to Oxman (2004) and Chiu (2010), design concepts of an architectural project depend solely on the knowledge of the design phase and thinking ability of the designers. Wang (2007) and Tseng *et al.*, (2008) believe that design concepts depend on the background information and experiences of the designers' previous design projects. On the other hand, the view of Al-Sayed *et al.*, (2010) is that implied and clear knowledge is the base of the construction design phase.

It is undoubtedly true that the use of pencil and paper in drawing and sketching in the early stages of construction design played an important role in determining and exploring the possible alternatives of design for architectural projects (Do, 2002). The traditional drawing and sketching process still plays a significant role in evaluating alternative ideas and communicating concepts throughout the design phase. On the other hand, CAD software has made the manual drawing and sketching process of the design phase more effective than the traditional drafting method in terms of costs, effectiveness and ease of use throughout the design phase. However, Oxman (2004) argues that this CAD software that can be used for drafting cannot be suitably used to carry out primary design works such as ideas generation and concepts communication.

In this design phase, it is critical for the designers to have enough data to be able to choose the structural system, interior design, building orientation and other crucial factors (Gervásio *et al.*, 2014; and Granadeiro *et al.*, 2013). These decisions are crucial for the architecture and construction projects, as assumptions about the structural system, interior plans, and building placements of the construction project using the predictive climate, geographical, and location-based information provide the foundation of the final outcome of the project. In this case, BIM has been effectively used as there is a need to manage the performance requirements of the building efficiency and the scarcity of valid information at the primary phase. BIM provides an adequate information database for the designers and enables them to determine the structural system and building orientation based on, for example, the existing environment and conditions of the location, temperature, daylight directions, and wind

directions. Again, Do (2002) states that BIM software has been essentially integrated with such information databases.

According to Do (2002), design software or tools must incorporate and be integrated with essential options to enable the designers to explore additional capabilities in the case of drafting and editing. With the use of BIM software, designers can now enjoy the enormous benefits it has to offer, such as visual analysis and representation, visual documentation of the reports, and design, drafting, scheduling and cost analysis for the project (Foqué, 2011). Moreover, with the help of BIM in the design phase, designers can analyze and evaluate the alternatives to the design, considering the same conditions and providing the required information about a certain project.

Conclusively, it can be stated that BIM offers significant information in the early stages of the design phase of a construction project, which is crucial for the thorough design of the project and for the final outcome of the architecture. Again, BIM software is considered to be an enhanced architecture package, along with the information databases, 2D and 3D standard drafting features, performance-based simulation capabilities, feedbacks on the designs, and visual representation and evaluation of the design. Garber (2014) explains that BIM not only provides a programmed and enhanced design process but also evaluates the alternative building forms and the factors related to the environment of the project.

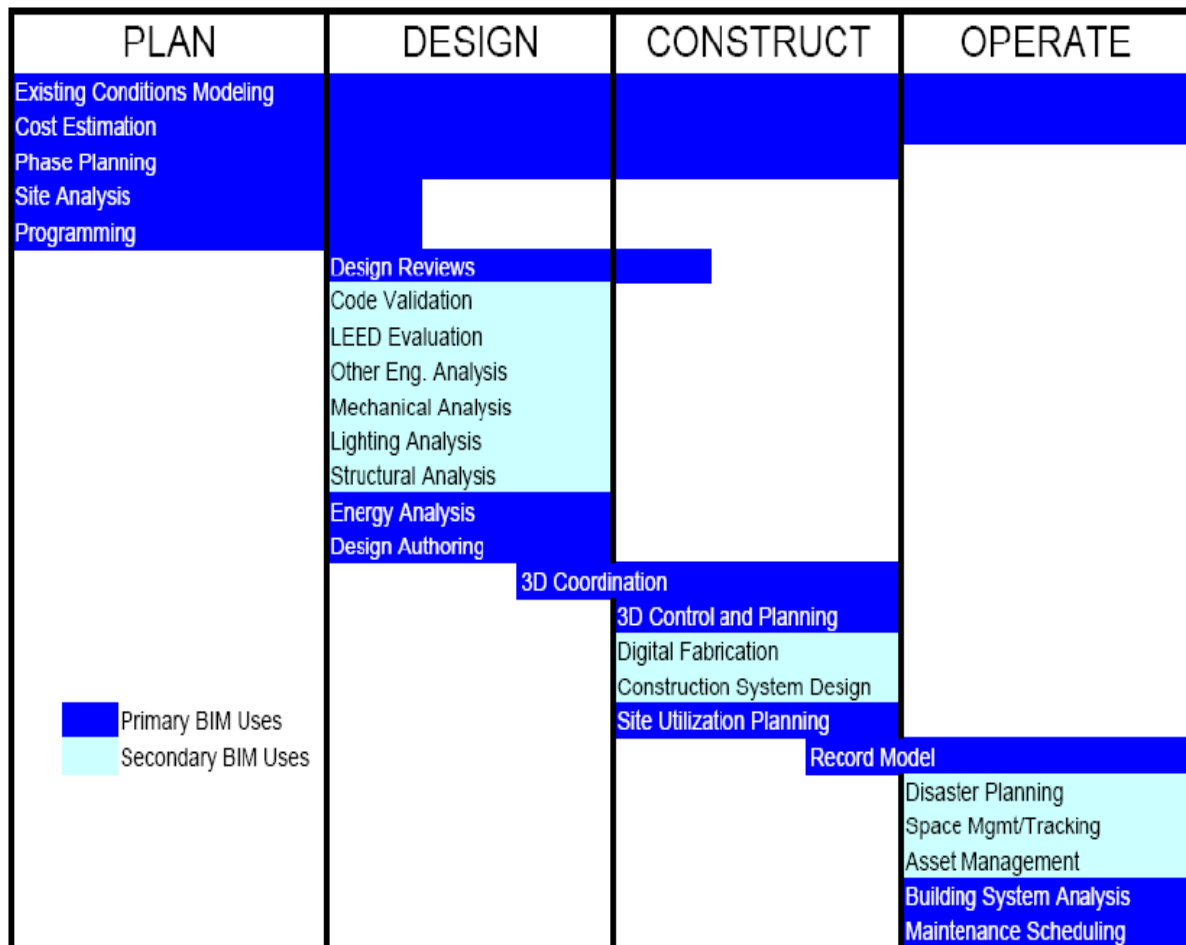
### **3.3.3 The Use of BIM in the Construction phase**

At different stages of a project, there are different usages of BIM. For example, for the planning, design, execution, and maintenance stages of a project there are different sectors where BIM can be used. It can be used in the planning phase of a construction project by enhancing the control over the overall project: as mentioned earlier, BIM has the ability to influence the costs of a project. According to Bew and Underwood (2010), with the use of BIM, the project team can come up with innovative ideas and solutions in anticipation of any issues which might increase the project costs. This can only be achieved with the closest collaboration and teamwork between the parties of the construction project. Collaboration among different stakeholders and parties associated with the project is a core benefit of BIM usage in the planning phase.

Moreover, energy and other resource analyses can also be evaluated with the help of BIM (Azhar *et al.*, 2011). It assists the construction managers of the project by generating 3D coordination among the contractors and subcontractors at the planning stage of the project

design. BIM provides a visual representation so that the owner of the project can see whether the design is up to the required standard (Azhar *et al.*, 2011).

According to Messner *et al.*, (2009), BIM has many uses throughout a construction project lifecycle. This is comprehensively illustrated in Figure 3.7 below. Whereby cost evaluation, on-site visual representation, and fabrication are the key advantages of BIM throughout the planning phase of a construction project.

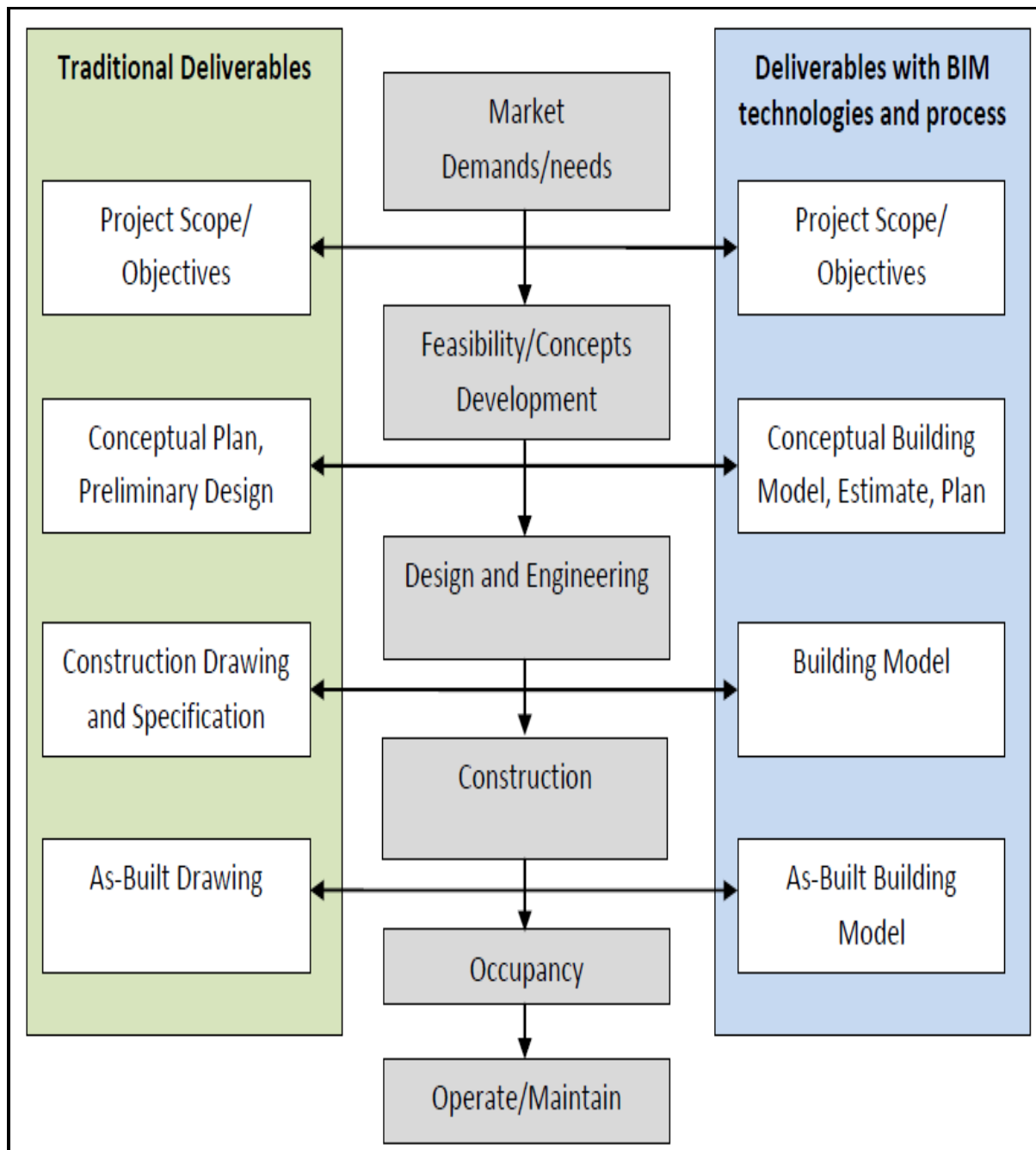


**Figure 3.7: BIM Uses Throughout a Construction Project Lifecycle**

(Source: Messner, 2009)

From the above analysis in Figure 3.7, it can be said that BIM can be effectively used at every stage of a construction project irrespective of the project deliverables (AIA, 2007; AGC, 2006; Eastman *et al.*, 2008). Moreover, in the case of the benefits of a construction project, the effectiveness of BIM can be enhanced during a project (Eastman *et al.*, 2008; AIA, 2007; Elvin, 2007) and can be applied for integrated practice in a construction project.

The following Figure 3.8 below shows the manifold use of BIM throughout the construction project.



**Figure 3.8: A Comparison of Deliverables Between Traditional Projects and BIM Integrated Projects**

(Source: Eastman *et al.*, 2008)

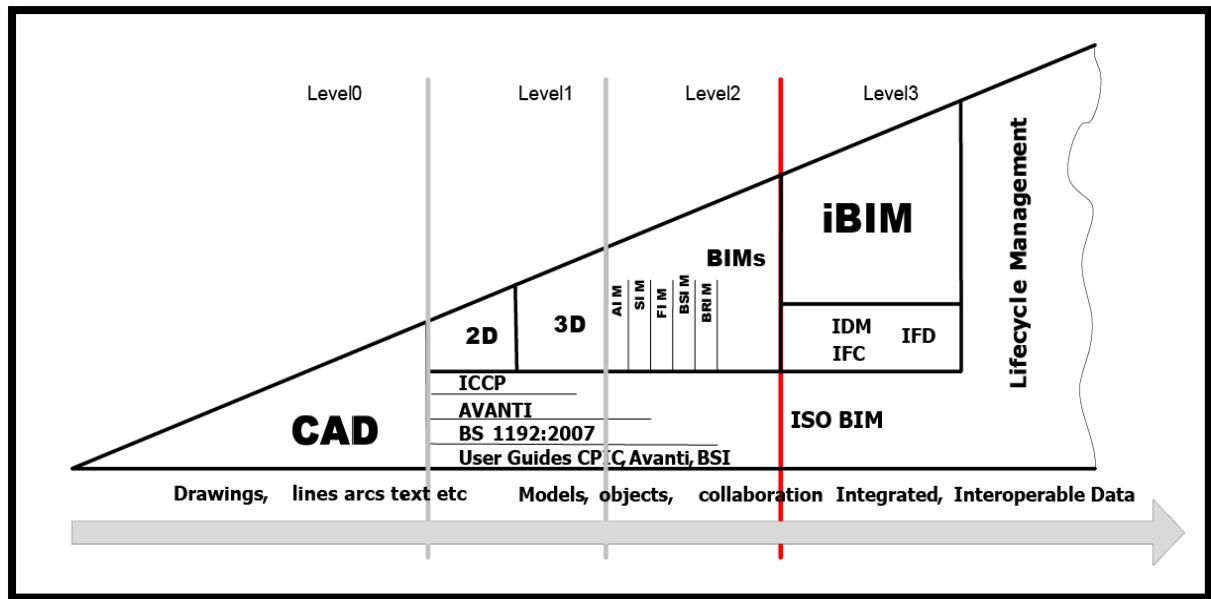
### **3.3.4 The Use of BIM in the Post-Construction Phase**

In the post construction phase, BIM can be used to plan and execute safe methods of operation and maintenance of the finished construction project. The operational phase normally includes 60% of total cost arising during the project construction. The activities that are happening during these operations are largely related to the concept of maintenance and repair (Sullivan *et al.*, 2010). Nevertheless, Eadie *et al.*, 2013, confirm that BIM is most often used in the early stages with progressively less use in the latter stages of a construction project lifecycle. Hence BIM is not being used to its full potential in the Facilities Management Phase.

In contrast the BIM model contains important information in terms of manufacturer specifications and maintenance instructions linked to the building components with the purpose of providing an accurate database for the client and operators (Sabot, 2008). Whereby each object in the BIM model can include links to operation, maintenance and warranty information. Therefore, in theory it can greatly contribute to the post construction phase and in particular to facilities management (Eastman *et al.*, 2008).

### **3.4 BIM LEVELS AND MATURITY**

Bew and Richards (2008) developed a model for UK BIM implementation which was re-developed and proposed by Bew and Underwood (2010) as the BIM evolutionary ramp from a construction perspective. According to Kang *et al.*, (2013), BIM has 4 distinct levels, each of which has different needs for resources, equipment, methods, and know-how. The model in Figure 3.9 below illustrates how the evolution of BIM progresses in four levels and each level requires different capabilities of people, process, and technology.



**Figure 3.9: BIM Evolutionary Ramp from a Construction Perspective**

(Source: Bew and Underwood, 2010)

Each level of this BIM Evolutionary Ramp is further discussed as follows: -

1. **Level 0:** at this level there is no collaboration in work between the designers, stakeholders and other teams in the construction project. Normally, a 2D CAD drawing is the outcome of this BIM level and is distributed as a printed version. It cannot be edited or modified further.
2. **Level 1:** at this level there is no collaboration in work between the designers, stakeholders and other teams in the construction project. Normally, a 3D CAD drawing is the outcome of this level, and is basically a conceptualized design, while a 2D drawing is required to obtain a legal authorization. This level was extensively used in the construction industry before the UK government mandate of using BIM Level 2.
3. **Level 2:** at this level there is an extensive collaboration in work between the designers, stakeholders and other teams in the construction project, where a 3D CAD drawing is used by the team members. This is the minimum level of BIM that is mandated by the UK government.
4. **Level 3:** this level is considered to be the gold standard of BIM. At this level there is extensive collaboration in work among all parties in the construction project. This level provides a complete view of the overall project life cycle, and with its help, one



can easily obtain the necessary information regarding the shelf-life of the construction project, which allows information regarding the demolition and regeneration of the construction project.

There are various benchmarks alluded to in the BIM evolutionary ramp which identify with each other through the procedure administration stages. Richards (2010) points out that there are some guidelines and regulations available which are provided by BS 1192:2007. In these guidelines, the correct standards are set out for organizing, managing, generating and storing building data related to the construction industry. According to BS 1192:2007, it is suggested that the Unified Classification for the Construction Industry should be used (Hunter and Kelly, 2009).

While COBie is not suggested in the above diagram, it is important for the movement of BIM (Jordani, 2010). COBie evaluates considers the exchanging of IFC-based organisation data (Jordani, 2010) and obtains this information incrementally, in the midst of the planning and development phases (Fallon and Palmer, 2007).

Most UK construction projects are at BIM level 1 and most of the renowned construction organisations are being encouraged by the government to jump to BIM level 2 (BSI, 2010). Moreover, in the case of public construction projects, project contractors and related staff, the UK government has made it mandatory to use BIM at level 2 since 2016 (Goubau, 2017). Here the UK Government Construction Strategy was instigated in 2011 with the intention of requiring BIM for all government projects by 2016 through a 5-year staged implementation plan. The government also established a dedicated BIM Task Group to assist in delivering this aim by providing support to the government and construction industry (McGraw Hill, 2014).

Furthermore, the British Standards Institute (BSI) released a PAS (Publicly Accessible Standard) PAS 1192-2:2013 'Specification for information management for the capital/delivery phase of construction projects using building information modelling' was developed as an industry standard to provide specific guidance for information management requirements associated with projects delivered using BIM (BSI, 2013).

Moreover, Scandinavian countries have been pioneers in BIM implementation. They have been working with BIM for over a decade now. The various governments in that region provide considerable support for the development and implementation of BIM technology.

The Finnish government has invested heavily in IT research in the construction industry (Granholm, 2011). In addition, they have released a universal BIM guide for their construction industry. Since 2007, the Finnish government-owned Senate Properties firm has required building models to meet Industry Foundation Classes standards (BuildingSmart Australasia, 2012). The Danish government too is an advocate of BIM and requires the use of BIM on all public projects (BCA, 2012). Denmark has also developed a new BIM classification standard that should be applicable for the whole of the European Union region (PR Web, 2013). In Norway, BIM implementation is led by the country's public construction and property management representative "Statsbygg". They have used BIM for their projects since 2007. This has required the use of open international standards in all public projects (Granholm, 2011).

The Singapore government has been the leader in the BIM adoption process and one of the few Asian countries that have implemented BIM in the public sector (Wong *et al.*, 2009). Singapore's Building Control Authority (BCA) has produced a five-year plan to move the industry towards the adoption of BIM. BCA will mandate "electronic submissions in BIM format for architectural, structural, mechanical and electrical plans for building works for regulatory approval by 2015, starting with architectural e-submissions in 2013" (BCA, 2013). Moreover, BCA has developed a fund especially dedicated to companies that are willing to adopt BIM. The fund pays part of the cost incurred in training, consultancy, software or hardware, up to 50% of the costs capped at \$35,000 per firm for the project collaboration scheme. These measures are applied to encourage companies to shift to BIM.

In the construction industry of Australia, however, the use of BIM is not widespread. Nevertheless, the Australian federal government proposed July 2015 for mandating BIM on all public projects and has taken the initiative for the development of the National BIM Guide, Australian and New Zealand Revit Standards and BIM-MEP AUS guidelines and models. The BuildingSMART organisation has been commissioned to prepare a strategy for BIM implementation that includes establishing an open BIM Alliance of Australia which should involve alliances with software vendors (CIBER, 2012).

North America has experienced one of the highest growths of BIM implementation globally, increasing from 28% of construction professionals using BIM in 2007 to 71% in 2012 (McGraw Hill, 2013). In the USA, the General Services Administration was the first government organisation to lead the US government into BIM and had a primary role in promoting BIM throughout the entire industry (National Institute of Building Sciences,

2011), where it required BIM for spatial validation on all projects. They have also developed a range of guidelines and standards that includes a National BIM Standard which is internationally recognized (CIBER, 2012). Moreover, in 2006 the U.S. Army Corps of Engineers published guidelines for implementing BIM, which were updated in November 2012 (US Army Corps of Engineers, 2012). Table 3.2 below summarizes the BIM initiatives in different countries of the world.

**Table 3.2: Summary of BIM Initiatives in Different Countries**

Country or Area	Summary of Actions to Implement BIM
<b>USA</b>	<p>In the USA, the General Services Administration (GSA) has been pioneering the adoption of BIM across publicly-funded projects.</p> <p>Moreover, the GSA has established a database of guidelines and best practices for BIM to be used in construction projects.</p>
<b>UK</b>	<p>The BIM industry working group in the UK has developed a set of guidelines and approaches to using BIM at level 2 on all public sector projects from 2016 onwards.</p>
<b>Singapore</b>	<p>In 2015, the Building and Construction Authority of Singapore announced BIM promotion planning. By 2015, nearly 80% of the construction projects in Singapore had used BIM.</p> <p>With the use of BIM, productivity in the construction industry has increased by 25% compared to previous decades.</p>
<b>Hong Kong</b>	<p>In 2014, the Housing Authority of Hong Kong mandated the use of BIM in all construction projects.</p> <p>The Housing Authority of Hong Kong developed a set of guidelines and best practices for effective BIM use and management.</p>
<b>South Korea</b>	<p>For all publicly funded projects and for projects worth more than 50 million USD, BIM use has been made mandatory in South Korea from 2016 onwards.</p>

(Source: adapted from BCA, 2013)

As BIM has been emerging all around the world in the construction industry, many notable approaches have been taken by different countries and their construction industries in order to implement BIM successfully. This section will discuss some of the best practices, strategies and innovative approaches towards its adoption and implementation.

According to Choi (2012), government and construction industry leadership is the main driver towards implementing BIM successfully. Similarly, Smith (2014) indicates that national leadership and collaboration with the construction industry is a crucial factor for a successful BIM adoption and implementation in increasing efficiencies of this technology. Smith (2014) emphasizes that such leadership approaches at government level will help in reducing the challenges that arise from disorganized and disorderly approaches. Quek (2012) argues that though such approaches should come from national leadership primarily, immediate and collaborative support should come from major industry players such as clients, construction industry professionals, and construction-based organisations and associations. Again, considering the global nature of BIM adoption and its world-wide application, global leadership has to come forward in facilitating BIM implementation. According to Kang (2015), if the strategy of BIM adoption is owner-driven then the probability of success in its implementation will be increased. Government initiatives and mandates in using BIM are an effective strategy to be imposed by national leadership towards BIM implementation (Kang, 2015). The UK, the USA, and Singapore governments have mandated the use of BIM in the case of publicly funded projects (Bin Zakaria *et al.*, 2013).

Again, there is a need for some global and national standards and guidelines to ensure the effectiveness of this technology. Standard BIM product databases and archives are also an important factor for its adoption and implementation. The UK government is now providing free universal access to a national BIM library for construction industry professionals and BIM practitioners in order to expedite BIM implementation at a global level (Jung and Lee, 2016). Again, Dong (2017), emphasizes the importance of BIM education, training and research activities in order to increase its adoption and implementation. Furthermore, Yoon *et al.*, (2015) believe that BIM training and education will not only increase its adoption and implementation but will also help in the evolution of a global construction industry. BIM education is needed at tertiary level education so that graduates who are about to enter the construction industry acquire sufficient knowledge and capabilities in relation to the adoption and use of BIM (Al-Mohannadi *et al.*, 2013). All these above-mentioned strategies are summarized in Table 3.3.

**Table 3.3: Comparative Listings of BIM Adoption Plans**

Plans For BIM Implementation	Authors
<ul style="list-style-type: none"><li>• Government and industry level leadership is necessary in implementing BIM (e.g. UK and USA governments have mandated the use of BIM in publicly funded projects)</li><li>• Support and collaboration from construction industry, leadership and government</li></ul>	Smith (2014)
<ul style="list-style-type: none"><li>• Focus on the competitive advantages of using BIM</li><li>• Focus on return on investment</li></ul>	Quek (2012)
<ul style="list-style-type: none"><li>• Free access to BIM product archives and online based BIM building product information is needed in order to facilitate and motivate the construction professionals</li><li>• Legal and contractual issues need to be considered</li></ul>	Yoon <i>et al.</i> (2015)
<ul style="list-style-type: none"><li>• BIM education and training for construction industry professionals need to be provided</li><li>• Setting national and global standards and standardized policies for BIM adoption, and implementing it to obtain its full potential</li></ul>	Al-Mohannadi <i>et al.</i> (2013)

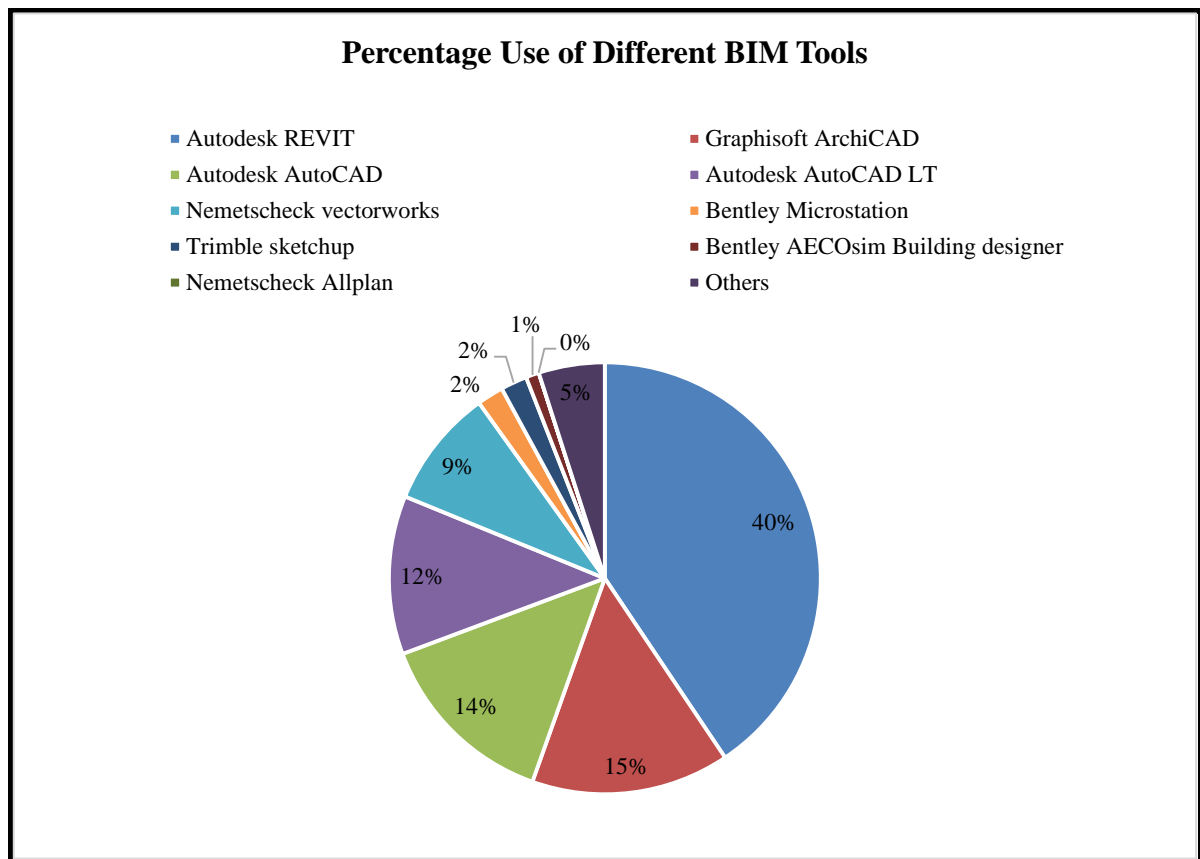
(Source: Compiled by Author)

There are many exemplars that can benefit from this research study as there is no doubting the increasing relevance of BIM to the international construction community. The countries mentioned above have a regulatory requirement for BIM or have produced a BIM guide or manual to assist in the promotion of BIM locally. Henceforth these countries are currently regulating the use of BIM on public sector projects. Accordingly, studying these countries' exemplars and their national BIM programme in detail could benefit this research study, especially where BIM is at a particularly mature level, in order to more thoroughly explore the individual programme themes identified for each country and select the most valuable details, as these requirements provide for a structured framework to support local government and other regulatory bodies who are required to work with BIM now and into the future. So the Saudi Arabian construction industry can embrace, adopt and implement a structured BIM programme in the near future.

### **3.5 IT REQUIREMENTS OF BIM**

Building information modeling software consists of computer-aided design (CAD) a computer system or now known as software to aid in the creation, modification, analysis, or optimisation of a design. This greatly assists the professionals and designers from the architecture and construction industries. Though the BIM technology is quite new, there are

many tools and software packages for BIM offered by various leading market players like Autodesk, Tekla, Graphisoft, CYPE, and Bentley. According to the NBS National BIM Report (2017), Figure 3.10 below shows the popularity levels of different BIM-related tools which are available and have been used by construction and architectural professionals and designers.



**Figure 3.10: Percentage Use of Different BIM Tools**  
(Source: NBS National BIM Report, 2017)

All these types of BIM software are designed for architectural design and construction, such as mechanical, electrical and plumbing (MEP) and building information modeling. So, the IT requirements for each of the software are different. As can be established from Figure 3.11 below, the 2017 version of Autodesk Revit requires Microsoft Windows operating system 64 bit for Windows 7, Windows 8.1 or Windows 10, and needs 4GB RAM and 5GB of available hard-disk memory to be free for the software to be installed and operate (Autodesk, 2017). Nearly 100 MB of memory needs to be available for general editing purposes for a single

model. For more critical project tasks, more memory on the disk would be needed. On the other hand, for previous versions of Revit more RAM speed and more available memory in the hard disk would be needed.

Autodesk Revit 2017	
Value: Balanced price and performance	
Operating System <sup>1</sup>	<p>Microsoft® Windows® 7 SP1 64-bit: Enterprise, Ultimate, Professional, or Home Premium</p> <p>Microsoft® Windows® 8.1 64-bit: Enterprise, Pro, or Windows 8.1</p> <p>Microsoft® Windows® 10 64-bit: Enterprise, or Pro</p>
CPU Type	<p>Multi-Core Intel® Xeon®, or I-Series processor or AMD® equivalent with SSE2 technology. Highest affordable CPU speed rating recommended.</p> <p>Autodesk® Revit® software products will use multiple cores for many tasks, using up to 16 cores for near-photorealistic rendering operations.</p>
Memory	<p>8 GB RAM</p> <ul style="list-style-type: none"> <li>Usually sufficient for a typical editing session for a single model up to approximately 300 MB on disk. This estimate is based on internal testing and customer reports. Individual models will vary in their use of computer resources and performance characteristics.</li> <li>Models created in previous versions of Revit software products may require more available memory for the one-time upgrade process.</li> </ul>
Video Display	1,680 x 1,050 with true color DPI Display Setting: 150% or less
Video Adapter	DirectX® 11 capable graphics card with Shader Model 5 as <a href="#">recommended by Autodesk</a> .
Disk Space	5 GB free disk space
Media	Download or Installation from DVD9 or USB key
Pointing Device	MS-Mouse or 3Dconnexion® compliant device
Browser	Microsoft® Internet Explorer® 7.0 (or later)
Connectivity	Internet connection for license registration and prerequisite component download

**Figure 3.11: IT and System Requirements for Autodesk Revit 2017 Version**

(Source: Autodesk, 2017)

On the other hand, ArchiCAD 21 can be used with both Windows and an iOS platform. Moreover, one of its products, BIMx, has both Android and iOS applications and is functional in smart phone devices. For ArchiCAD, only a Windows 64 bit system will be

supported and 4 GB of RAM is required. There are a few applications that allow BIM to be used in smart phone devices and in tablets. For instance, Tekla BIMsight 1.4 can be used in tablets and is a cost-free application for plan coordination and BIM joint effort (Tekla BIMsight 2017). Full Tekla BIMsight can be utilized on Windows tablets on location and moving when one has to join exchange models and perform spatial coordination.

### 3.6 GLOBAL PROJECT EXEMPLARS OF USING BIM

On a worldwide level, BIM is causing a transformation that has changed the construction business. The USA, UK and Australia are consistently advancing their use of BIM tools and applications due to two noteworthy advantages that the construction organisations can gain for it such as an increase in business development, increase in financial revenue and a saving of time. In North America, in only 5 years (2007-2012) BIM utilization has increased from 28% to 71% (TIMETRIC, 2016).

The following Table 3.4 below will provide a glimpse of projects undertaken with the use of BIM in different countries around the world.

**Table 3.4: Outlining Some Different BIM Based Projects Around the World**

<b>UNITED STATES</b>	
<b>Project: Memorial Hospital, Colorado</b>	
Contractor: PCL	
Implications of BIM:	
<ul style="list-style-type: none"> <li>• 3500 reworks avoided; 500 of which were considered ‘grave’.</li> <li>• Cost savings through clash detection</li> </ul>	
<b>Project: Silver line, Telluride</b>	
Contractor: PCL	
Implications of BIM:	
<ul style="list-style-type: none"> <li>• Underestimation of excavated quantities detected ahead of construction</li> <li>• Cost savings of \$3 million</li> </ul>	
<b>Project: Spring Field Literacy Centre</b>	
Contractor: Burt Hill	
Implications of BIM:	
<ul style="list-style-type: none"> <li>• Elimination of redundant information</li> <li>• Improved communication</li> </ul>	
<b>Project: Crate and Barrel Group of Stores</b>	
Contractor: Crate and Barrel	
Implications of BIM:	
<ul style="list-style-type: none"> <li>• Reduction of average project weights from 190 tons to 170 tons</li> <li>• Reduction in prefabrication time from 6 weeks to 2 weeks</li> <li>• Reduction in time for shop drawings from 6 weeks to 3 weeks</li> </ul>	



- Reduction of time for erection from 6 weeks to 3 weeks

## HONG KONG

### **Project: One Island East**

Contractor: Swire Properties Ltd

Implications of BIM:

- Cost savings from prior identification of over 2,000 clashes
- Time savings of 20 days
- Order of magnitude reduction of contractors; request for information (RFIs)

## UNITED KINGDOM

### **Project: St Helen and Knowsley**

Implications of BIM:

- Time savings of 6 months
- 60-70 % savings in time to find documents
- 75-80% savings in design coordination efforts

### **Project: Festival Place, Basingstoke**

Implications of BIM:

- Estimated cost savings of 9% realized in the construction phase

### **Project: Palace Exchange, Enfield**

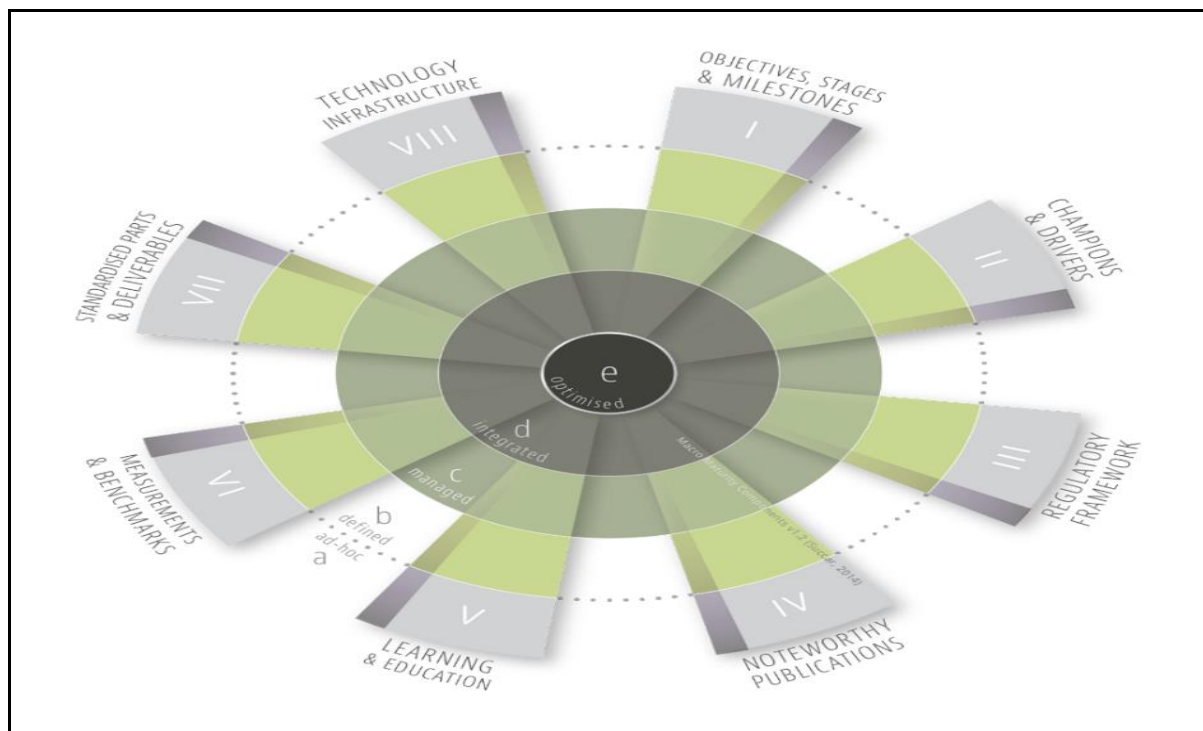
Implications of BIM:

- Nearly 800 man hours saved

(Source: adapted from Young *et al.*, 2009; Nisbet and Dinesen 2010;  
Riese and Shelden 2011)

A framework represents a holistic relationship of terms and concepts of a system (Jung and Gibson, 1999). It aims to sort out the logical structure of the interested system as well as the direction of future development (Jung and Joo, 2011). Similar to the framework, the model can be defined as the representation of a reality in a specific environment (Dehe and Bamford, 2015). Developing such a framework for BIM will enable all practitioners to be fully aware of the composition of the BIM concept. However, although frameworks, guidelines and protocols have been developed to facilitate the successful adoption of BIM, the issue is not a case of one size fits all. Investigations into BIM implementation across markets have been comparatively rare in spite of an ever-increasing range and depth of national BIM initiatives (NBIs) and noteworthy BIM publications (NBPs) (Kassem *et al.*, 2013). It is preferable for the construction industry to have a common digital foundation in every country that faces political and legal barriers. The willingness and ability for a project process simulation at the design phase creates the power to implement BIM technology. It has become a stronger tool for public procurement and for government policies (EUBIM Task Group, 2017).

Succar and Kassem, (2015), have carried some important and early work in global BIM adoption. One of their models, the Macro Maturity Components Model, identifies eight complementary elements in Figure 3.12 for measuring the BIM maturity of countries and assisting policy makers to develop BIM adoption policies.



**Figure 3.18: The Macro-Maturity Components Model**

(Source: Succar and Kassem, 2015)

The macro maturity components model identifies eight complementary components for measuring and establishing the BIM maturity of countries and other macro organisational scales. The eight components are: Objectives; Stages & Milestones; Champions & Drivers; Regulatory Framework; Noteworthy Publications; Learning & Education; Measurements & Benchmark; Standardized Parts & Deliverables; and Technology Infrastructure. The model can be used holistically by using a comparative matrix (low detail ‘discovery’ assessments), or granularly by using component-specific metrics (higher detail ‘evaluation’ assessment) for assessing and comparing the BIM maturity of countries.

Here the Macro maturity components are assessed using the BIM Maturity Index (BIMMI) which includes five maturity levels: [a] Ad-hoc or low maturity; [b] Defined or medium-low

maturity; [c] Managed or medium maturity; [d] Integrated or medium-high maturity; and [e] Optimized or high maturity (Succar, 2010).

Furthermore, the UK National Building Specification (NBS RIBA, 2016) has developed (inspired by the Chemical Periodic Table of the Elements), the Periodic Table of BIM, for a visual guide to the many key terms about the main concept and all factors related to BIM adoption. Introducing this table to the public sector makes the beginning of this knowledge easy for all stakeholders in the industry to share and develop it for the future. The following Figure 3.13 represents the periodic table of BIM.

The Periodic Table of BIM is a grid of 78 elements, each representing a BIM-related concept. The elements are organized into groups and periods, with color-coded categories. The categories are: Strategy (green), Foundations (orange), Collaboration (purple), Process (light blue), People (yellow), Technology (dark blue), Standards (light green), Enabling Tools (light orange), and Resources (grey). The elements are arranged in a grid that follows the periodic table structure, with some elements having subscripts or superscripts. The elements are: Bs (BIM Strategy), Fr (Framework), Cu (Culture and behaviour), Co (Common methods), Po (Process), As (Assessment and need), Eir (Employers info requirements), Cm (Communication), In (Investment), Sf (Software), Cd (Capital delivery plans), Cl (Collaborative business relationships), Li (Library objects), Cs (Classification), An (Analysis tools), Ev (Events), Bt (BIM Toolkit), Lod (Level of detail), Loi (Level of information), Vi (Videos), Pr (Procurement route), Fo (Forms of procurement), Ex (Execution), Bep (BIM execution plan), So (Soft skills), Ch (Change process), Ha (Hardware), Op (Operational phase), Pt (Protocol), Pe (Pregovernmental digitalisation), Cafm (Computer-aided Facilities Management), Ct (Cost tools), Fu (Forums and user groups), Ca (Capability and capacity), Di (Digital tools), De (Delivery), Midp (Master information delivery plan), Cp (Cooperation), Sh (Share success), Tr (Training), Fm (Facilities management), Qu (Quality management systems), Bsdd (BuildingSMART data dictionary), Pg (Programme tools), Ad (Administration tools), Sc (Social media), St (Standardisation and interoperability), Ma (Maintenance and use), Cde (Common data environment), Ci (Champion), Av (Availability), Fi (File storage), Dg (Digital security), Ds (Design management systems), Ifc (Industry foundation classes), Au (Authoring tools), Mo (Model viewers and editors), Bl (BIM points), Dpow (Digital Plan of Work), If (Information exchange), Sp (Support), En (Engage), Ir (Infrastructure), Br (Briefing), Am (Asset management), Idm (Information delivery manual), Sp (Specification tools), Fl (File sharing and collaboration), Bo (Books), Sr (Strategy), Bi (Brief), Df (Definition), Dn (Design), Bu (Build and commission), Hn (Handover and closeout), Oe (Operation), and Ed (End of life). The table is titled 'Digital Plan of Work stages' at the bottom.

**Figure 3.13: Periodic Table of BIM**

(Source: NBS RIBA, 2016)

Moreover, the European Parliament has introduced a set of reforms to the European Union (EU) Public Procurement Directive to help reduce unpredictable costs and project overruns (EUBIM Task Group, 2017). It encourages some EU nations to adopt BIM mandates or policies. With the influence of the BIM Special Interest Group (BIM2AIM), the UK Ministry of Justice completed its industry BIM practice guidelines in 2016. Current developments such as the “Digital BIM toolkit” to collect and validate data from Level 2 BIM (Ciribini *et al.*,

2015) and the 2016 guidelines are some of the main reasons why the UK has become a key player to be followed by the rest of Europe.

OpenBIM was initiated by Graphisoft, Tekla and other sponsors as a universal approach to the collaborative design, realisation and operation of the building based on open standards and workflows. OpenBIM is nowadays intended to be an initiative of several leading software vendors using the exchange-data model, through BuildingSMART alliance, Industry Foundation Classes (BuildingSMART, 2017).

Likewise, the Malaysian Public Works Department (PWD) introduced BIM into their construction industry in early 2007. However, the adoption and implementation of BIM in Malaysia took a long time. It eventually took place in 2010, when the National Cancer Institute construction project was undertaken (Latiffi *et al.*, 2016). As it is the national agenda to embrace new technology in the Malaysian construction industry, recently many private sector construction organizations have also taken actions by adopting and implementing BIM.

Moreover, to promote this new technology, the Construction Industry Development Board of Malaysia organizes various programmes in order to improve the adoption rate in the construction organizations. In 2014, the Construction Industry Development Board of Malaysia developed a BIM roadmap built on seven pillars (as shown in Table 3.5 below): Standards and Accreditation (P1), Collaboration and Incentives (P2), Education and Awareness (P3), National BIM Library (P4), BIM Guidelines and Legal Issues (P5), Special Interest Group (P6) and Research and Development (P7). The seven pillars were designed by the Construction Industry Development Board of Malaysia in order to enable many organizations to adopt and implement BIM within the country.

**Table 3.5: Summary of Seven Pillars for Malaysian BIM Roadmap**

Item No.	Pillars	Activities
1	Standards and Accreditation (P1)	BIM standards and common practices, guidelines, reference documents, accreditation for certification of BIM projects.
2	Collaboration and Incentives (P2)	Collaboration with other bodies and vendors, BIM funds and supports including costs of software, hardware and training).
3	Education and Awareness (P3)	BIM conference, competition, promotion, awards, training modules and syllabus.
4	National BIM Library (P4)	BIM library standard, cloud computing, national BIM library

5	BIM Guidelines and Legal Issues (P5)	National BIM guide, legal issues
6	Special Interest Group (P6)	BIM committee to share the information
7	Research and Development (P7)	Research funds and sponsors

(Source: Adapted from Construction Industry Development Board Malaysia, 2014)

BIM implementation frameworks, standards, guidelines, execution plans, protocols and maturity models facilitate successful BIM implementation. Kassem *et al.*, (2013) contends that most implementation frameworks and maturity models are focused on the individual construction organisation but there is a need for countrywide maturity/engagement scales and models. BIM adoption surveys can form the starting point for countrywide measures of BIM maturity. Kassem *et al.*, (2013) further cite the adoption of BIM in Australia, the United Kingdom and the United States as examples of metrics that can be utilized in a country's BIM model. Comparing the best practice of other peers could also reveal the defects of current practice and an appropriate improvement strategy could be planned and proposed accordingly (Succar and Kassem, 2015; Camp, 1995).

Jung and Joo (2011) proposed a framework to systematically represent the relevant areas of BIM practical implementation. Additionally, frameworks have been proposed by individual researchers for BIM implementation in countries such as Jordan, Iraq, China, Malaysia and India. Nevertheless, the proposed frameworks are not comprehensive enough. Limitations, for example, are such that the degree of involvement of all partners during BIM implementation should be considered. Moreover, the frameworks need to be kept up to date, as the business function during the operation stage should be considered, since the information required for building operation purpose should be prepared in early design stages. Most importantly, no follow-up research has been suggested in order to develop evaluation methodologies based on Jung and Joo's framework.

By considering BIM as the integration of the final product and the process of delivering it, users will begin to understand, disseminate and incrementally implement BIM. In addition, a framework that could achieve "presenting data and arguments in manageable sections" could fill the gap that remains between academic and industry knowledge bodies (Succar, 2009). Thus, the objective of this research is to explicate the BIM adoption factors from various literature sources, as a basis for developing a research framework that will then fill the

existing gap relating to BIM adoption and implementation in the Saudi Arabian construction industry.

In doing this, the NBS periodic table of BIM implementation is deemed very appropriate and applicable for the development of a strategic framework for BIM adoption. The choice of the periodic table for BIM implementation as the basis for developing the framework for BIM implementation in Saudi Arabia was based on the links between the aim of the research and the elements of the periodic table.

### **3.7 BENEFITS OF BIM**

In order to promote the adoption and implementation of BIM at all levels of the construction industry, it is essential to understand the core benefits it has to offer. Race (2013) notes that most of the construction industry professionals used to face challenges regarding the traditional CAD design and drafting. Due to the complexities associated with traditional CAD design, the productivity and cycle time of the project tended to become reduced to a serious extent (Race, 2013). In this case, it would be an effective help for the construction organisations if they could fully understand the benefits of BIM adoption and implementation within their project. With the help of BIM, construction organisations can strategically decide on their work activities in order to meet their project aims and objectives. Throughout this study, therefore, the benefits of BIM are discussed, so as to provide an understanding of BIM adoption and implementation.

BIM helps in reducing the quantity of requests for data and modifications needed for the project, and accordingly enhances profitability (Eastman *et al.*, 2008 and Kaner *et al.*, 2008). Again, Kaner *et al.* (2008) investigated the increase in profitability for delivering basic design illustrations with rebar itemizing, which has yielded an increase from 21% up to 59%, contingent upon the size, quality, and uniformity of the structures. The profitability and enhanced nature of plans and documentation drive the execution of BIM to accomplish efficiency upgrade.

The utilisation of 3D parametric modelling apparatuses in BIM enhances the clearness of portrayal of the outline aim and steady illustrations generation. Any logical inconsistencies in the interior design in the substance of any individual report or related arrangements of records are wiped out and the expansion in clearness and consistency prompts a substantially more proficient outline creation process inside the associations and enhances the cooperation and correspondence between stakeholders and clients of the project (Bryde *et al.*, 2013; Atazadeh

*et al.*, 2016). Kang (2015) hypothesizes that the BIM representation could be of assistance over the whole project lifecycle. It can be said that, in the case of a construction project, visual representation helps the designers to work cooperatively and convey their thoughts about the plan more proficiently as each project member has a similar 3D configuration. Moreover, constructability issues among site engineers and designers can be reduced with the help of the visual representation provided by BIM. Some other benefits of BIM are listed below:

**a) Easy Verification of Consistency**

A visual 3D representation of the components needed for the project can be viewed with the help of BIM, such as the materials needed for the construction, spaces required and other components. This will give an overall cost estimation for the project (Kumar, 2012). This feature of BIM is essential for technical buildings like hospitals or laboratories.

**b) Extraction of Cost Estimates During the Planning Phase**

In the planning stage of the construction project, BIM technology can extricate the associated costs of materials and labors needed for the project completion in full so these costs can be utilized for an estimation at the initial stage of the construction project (Marzouk and Hisham, 2012). In the early stages of project planning, cost estimations are constructed in the light of equations regarding critical task amounts: for instance, the number of parking spots, the area of the selected place, or the costs needed to build each unit of the area. As the project advances, more definite amounts are accessible and can be utilized for more exact and accurate cost estimations. In the final phase of project planning, a cost estimation relating to the amounts for every one of the components contained inside the model takes into account the arrangement of a more precise final cost estimation. Therefore, the most suitable plan alternatives can be decided on with respect to costs, by utilizing BIM as opposed to a paper-based framework (Kim *et al.*, 2013).

**c) Spontaneous Modification in the Case of Any Design Change**

When any resources or materials are utilized as a part of the project they are controlled by parametric guidelines that guarantee a legitimate arrangement. At that point the 3D design usually does not have any particular shape, arrangement, or three-dimensional coordination errors (Dore and Murphy, 2013). Kim and Yun (2017) point out that this lessens the client's concerns when managing the project.

#### **d) Precise and Reliable 3D Models**

Precise and predictable illustrations are obtained for different arrangements of items or indicated perspectives of the task. This fundamentally decreases the length of time and number of mistakes related to the construction project drawings, in all aspects (Yoon *et al.*, 2015), and at the point when changes to the plan are required, completely predictable illustrations can be created when the outline alterations are made.

#### **e) Cooperation Within Teams Before Finalizing Design**

Instantaneous activities can be performed using BIM technology. Change management and change control can be planned and maintained in a proper way with the help of the 3D model collaboration in BIM (Kang *et al.*, 2015). As a result, design time can be minimized to a great extent and the probability of errors or complexities can be reduced as well. It also provides a better understanding about the complexities associated with project planning and enables construction organisations to improve such planning (Kim *et al.*, 2013).

After a thorough review of the literature, other benefits of BIM are found to be as follows:

1. BIM creates accurate and standardized construction documents (Logothetis *et al.*, 2016),
2. BIM can undertake 3D visualisation, renderings and fly-through (Kim *et al.*, 2013)
3. Without any impact on the quality, drafting can be done faster than when using conventional drafting methods (Race, 2013).
4. Monotonous components can easily be incorporated within the design without wasting further time (Paruch, 2015).
5. Clash analysis and risk assessment can be conducted using BIM at the primary design stage: in other words, even before the actual construction takes place (Eastman *et al.*, 2011).
6. Quantity surveys and cost estimation become easier and more accurate with the use of BIM (Marzouk and Hisham, 2012).
7. Time management and project management can be performed in an organized manner with the help of BIM and the construction simulation can be visualized using BIM (Azhar, 2011).
8. The length of time for scheduling the project from the concept to completion is reduced, by using the building model (McCuen, 2008; Eastman *et al.*, 2011),



9. Financial risk is minimized when BIM is used early to estimate the cost effectively and improve the relationship between the project team members (McCuen, 2008; Eastman *et al.*, 2011),
10. Any change or modification made during the initial planning or design stage of the construction project can be tracked through the use of BIM which in turn can ensure better transparency and effective change management among the construction professionals (Langroodi and Staub-French, 2012).
11. Material wastage can be reduced to a minimum level with the use of BIM as it enables offsite production (Eastman *et al.*, 2011, Lu and Korman. 2010).
12. The processes of facility management and asset management become much easier with the use of BIM (Eastman *et al.*, 2011, Kelly *et al.*, 2013).
13. BIM helps the construction industry professionals to adhere to the government's regulatory rules and requirements (Azhar, 2011).
14. Different options of design can be simulated with BIM and from this the best alternative can easily be selected (Zhang and Hu, 2011, Lee *et al.*, 2012, Zhou *et al.*, 2013).
15. Energy analysis (Bynum *et al.*, 2013, Azhar, 2011), as well as CO<sub>2</sub> and greenhouse gas (GHG) emission analysis (Li *et al.*, 2012) can be performed with the help of BIM

From the above discussion about the benefits of BIM, it is certain that with the use of BIM in construction projects, the overall cost can be reduced and the project can be completed within the scheduled timeline. However, the costs associated with the adoption of BIM and the implementation of BIM-related software and hardware need to be taken into consideration during the cost estimation of the project (Vogt, 2010). Eastman *et al.*, (2011) suggest that the costs incurred as a result of the implementation of BIM can be reimbursed through the extensive benefits it brings throughout the lifecycle of the project. Moreover, BIM-Management (2013) estimates that construction organisations can usually save up to 20% of the project costs with BIM implementation, including the costs associated with the conversion of 2D designs into 3D simulations. With the clash detection feature of BIM, change management is possible within a construction project and project delays can be

reduced to the minimum. The following Table 3.6 outlines the benefits of BIM as proposed by different authors.

**Table 3.6: Various Benefits of BIM Usage Based on Different Author's Views**

Author	<i>Arayici 2012</i>	<i>Abdulkadir and Godfaurd (2017)</i>	<i>Rahman et al., (2016)</i>	<i>Zhao et al., (2015)</i>
<b>Suggested Benefits</b>	<ul style="list-style-type: none"> <li>• Faster and more effective processes.</li> <li>• Better design.</li> <li>• Controlled whole life costs and environmental data.</li> <li>• Better production quality.</li> <li>• Automated assembly.</li> <li>• Better customer service.</li> <li>• Lifecycle data.</li> <li>• Integration of planning and implementation processes.</li> <li>• Ultimately, a more effective and competitive industry and long-term sustainable regeneration projects.</li> </ul>	<ul style="list-style-type: none"> <li>• Visualisation</li> <li>• Scope</li> <li>• Clarification</li> <li>• Partial Trade Coordination</li> <li>• Collision Detection/Avoidance</li> <li>• Design Validation</li> <li>• Construction Sequencing</li> <li>• Planning/Phasing Plans</li> <li>• Site Logistics</li> <li>• Hazard Perception</li> <li>• Health and Safety Site Issues</li> </ul>	<ul style="list-style-type: none"> <li>• Easier Coordination of different software and project personnel</li> <li>• Improved Productivity</li> <li>• Improved Quality control</li> </ul>	<ul style="list-style-type: none"> <li>• The data model will exist for the life of a building and can be used to manage the client's asset.</li> <li>• Reduced risks</li> <li>• Improved Productivity</li> <li>• Streamlined Production</li> <li>• Maintenance of design intent</li> <li>• Facilitation of quality control through clear communication and sophisticated analytical tools.</li> </ul>

(Source: Compiled by Author 2017)

### 3.8 BARRIERS TO THE ADOPTION OF BIM IN THE CONSTRUCTION INDUSTRY GLOBALLY

From the above discussion on the benefits of BIM technology in the field of construction, building design, management and maintenance of the buildings, it is confirmed that BIM technology has much to offer to the construction industry. Nonetheless, the barriers and challenges in adopting and implementing this new technology in the construction industry by replacing the traditional concepts cannot be overlooked. Kiviniemi *et al.*, (2008), points out four key barriers in adopting BIM technology, as follows:

1. **Legal challenges:** which are related to the legal issues related with the models

compared to the documents. Such issues may arise where responsibilities for the data content in BIM models are undefined.

2. **Business issues:** which are mainly concerned with the distributions and provisions of various roles and responsibilities during the whole process of BIM adoption and implementation (Eadie *et al.*, 2014).
3. **Human problems:** which are concerned with the stress and reluctance to change from a traditional system to a new one.
4. **Technical issues:** which can arise mainly because of the immaturity of the BIM software, especially in the case of data transmission and interoperability (Eastman *et al.*, 2008).

According to the survey conducted by Yan and Demian (2008) among 70 participants from the construction industry of the UK and the USA, human issues are considered to be the main barriers in implementing and adopting BIM technology. From the responses of these participants during the survey, Yan and Demian (2008) found out that time constraints and the lack of human resources needed for the training of BIM technology are the main challenges to BIM adoption. Moreover, participants pointed out some other barriers to this adoption, such as fear of change and reluctance to move away from traditional methods; costs of patents; and the inappropriateness of BIM for some projects. Even some of the participants mentioned that they felt that current methods in building design were enough for them and so they were not willing to adopt new technology which they did not know well.

According to Mehran (2016), the top obstacles to BIM adoption are as follows:

- Inadequate training
- Senior management buy-in
- Cost of software
- Cost of required hardware upgrades
- Risk of losing intellectual property; liability issues; sharing of information between, contractors and facility owners

Mahamadu *et al.*, (2017) point out the drawbacks for construction industries in admiring and executing BIM technology. The roles and responsibilities of every stakeholders and member of staff are pre-defined traditionally, while clients and stakeholders do not seem to be flexible in adopting new technologies.

From the study conducted by Ku and Taiebat (2011) on the US construction industry it was found that the main obstacles to the adoption of BIM in the construction industry of the United States of America were as follows:

- Lack of standardized regulations
- Lack of collaboration during the construction project and work process
- Lack of investment to support the initial costs of BIM implementation
- Unwillingness and reluctance of the stakeholders (architects, engineers, and contractors) in adopting BIM
- Lack of skilled personnel with proficient knowledge about the BIM technology

Ku and Taiebat (2011) believe that the reluctance of designers to adopt BIM to its full potential is another barrier. On the other hand, Ngowtanasuwan and Hadikusumo (2017) argue that BIM designers are not compensated and rewarded for all the cost-effective projects and improved efficiency attributed to the use of BIM technology during the construction project, and this reduces the motivation of the designers to adopt BIM to its full potential. Again, Masood *et al.*, (2014) identify the major barriers to BIM adoption as being the lack of well-trained and knowledgeable professionals, lack of guidance and support from the government, and lack of standardized regulations and policies from the policy-makers. Matarneh and Hamed (2017) in their study show that lack of government support and initiatives, and government reluctance in mandating the adoption of BIM in at least publicly-funded construction projects are the major barriers to BIM adoption. Again, they highlight the lack of BIM standards and policies for BIM implementation; lack of BIM awareness and lack of knowledge about the benefits of BIM among the construction industry stakeholders; and lack of demand from clients and construction firms, all of which are presenting critical challenges to the adoption of BIM (Matarneh and Hamed, 2017).

The following Table 3.7 presents a compilation of barriers to BIM adoption, from various studies found in this literature survey.

**Table 3.7: A Comparative Listing of Barriers to the Adoption of BIM**

Barriers in Adopting BIM	Authors
<ul style="list-style-type: none"> <li>• Lack of knowledge and awareness about BIM among the construction industry professionals and clients</li> <li>• Lack of guidance and support from government</li> <li>• Lack of standardized regulations and policies from the policy</li> </ul>	Bin Zakaria <i>et al.</i> , (2013)

makers	
<ul style="list-style-type: none"> <li>• Costs related to the implementation of BIM</li> <li>• Unwillingness to adopt new technology</li> <li>• Lack of effective training and resistance to learning new technology about BIM</li> </ul>	Abubakar <i>et al.</i> , (2014)
<ul style="list-style-type: none"> <li>• Lack of training and knowledge about BIM and its benefits</li> <li>• Lack of proficient and knowledgeable construction professionals</li> <li>• Inadequate demand from clients and lack of willingness of the stakeholders to adopt BIM</li> </ul>	Chan (2014)
<ul style="list-style-type: none"> <li>• Unwillingness to shift from traditional methods to BIM</li> <li>• Lack of interoperability and consistency</li> </ul>	Rogers <i>et al.</i> , (2015)
<ul style="list-style-type: none"> <li>• Unwillingness to change organisation culture</li> <li>• Intangible nature of the benefits</li> <li>• High implementation costs</li> </ul>	Khosrowshahi and Arayici (2012)
<ul style="list-style-type: none"> <li>• Inadequate resources in adopting and implementing BIM in construction industry</li> <li>• Lack of understanding about the diversity of BIM</li> </ul>	McAuley, Hore and Deeney (2013)

(Source: Compiled by Author, 2017)

### 3.9 THE AWARENESS OF BIM IN SAUDI ARABIA

Researchers from Saudi Arabia, such as Al-rashed *et al.*, (2014) and Sidawi and Al-Sudairi (2014), expect that BIM will advance conventional construction project management methods and techniques in the Saudi Arabian construction industry, and as such these methods and techniques will drive the adoption of BIM in the construction organisations. Many different factors support this view, including the prospect of growth in revenue, an increase in competitive pressure, and the capability to compete globally and tackle the challenges of the market by re-engineering the business (Sidawi and Al-Sudairi, 2014). Furthermore, Ahuja *et al.*, (2010) state that the adoption of computer-based ICT by the construction industry will allow for successful communication amongst the project team members and stakeholders who are usually widely dispersed. Ahuja *et al.*, (2010) and Al-shawi *et al.*, (2009), are both of the notion that the strategic adoption of ICT requires all organisations in the construction process and its associated supply chain to adhere to the accepted protocols of communication in order to enable them to grasp the benefits of IT effectively.

BIM is a modern IT tool that can benefit the construction industry of Saudi Arabia in many ways, as the country has to optimize national spending to enhance the value of its expenditure. In view of this, BIM would be an effective tool to implement in the construction industry as it will help in minimising the requirement of different resources and will enable all stakeholders and construction industry personnel to visualize their project design and decide effectively. With the use of BIM, the extra cost, expenditure and modification in project design can be adjusted or prevented effectively. These benefits are some of the major concerns of the Saudi Arabian construction industry at present. Assaf and Al-Hejji (2006) found that more than 70% of the construction projects in Saudi Arabia faced time and budget constraints due to requests for change. With the use of BIM to reduce waste, the Saudi Arabia government and the construction industry would be able to halt the economic decline in this industry and would be able to take on value-added construction projects.

As a technology driven concept, BIM would help the construction industry of Saudi Arabia in developing a visualized virtual design for the construction process of a building structure before building its physical structure (Azhar *et al.*, 2011). With the use of BIM in Saudi Arabia's construction projects uncertainty regarding the construction process could be reduced to a minimum level while safety would be ensured. Thus BIM can bring far greater effectiveness as it energizes the coordination of all the stakeholders of the project and the organisational practices into a synergistic procedure that empowers the reduction of resources and enhancement of proficiency through all periods of construction projects in Saudi Arabia (Ikediashi *et al.*, 2014). BIM can also be utilized for the upkeep and office administration of the working after completion of the project.

BuildingSmart (2011) conducted a survey regarding awareness of BIM in the Middle East which revealed that in the case of BIM adoption, the countries that belong to the GCC (now the Cooperation Council for the Arab States of the Gulf, but still known as the Gulf Cooperation Council) are still lagging behind the global trend. However, regarding awareness of the benefits of BIM in the construction industry, the report by BuildingSmart (2011) revealed that there is a high level of awareness of the advantages of BIM among the GCC countries. According to the survey data, it can be said that UAE (United Arab Emirates) has the greatest BIM awareness (about 77%) while in Saudi Arabia it was nearly 41%, followed by Qatar (35%). During the survey, participants from different roles in the construction industry were chosen, including contractors (36% of overall participants), and government authorities, clients, staff, and developers (8-10%). According to the responses

from the participants, it was found that nearly 25% of the construction projects used BIM, which is regarded as a medium level of usage, considering the BIM adoption percentage of North America (49%) and Western Europe (36%). Moreover, it needs to be noted that in the case of construction projects in the Middle East, BIM has only been used for particular purposes and not as an integrated tool for construction projects (Building SMART ME, 2011).

There are several reasons why construction industry professionals and contractors are not using BIM or BIM-based tools for their purpose. The main reason is that there is a lack of awareness in the Middle East regarding the use of BIM. Moreover, an adequate training and education system is not available for the contractors and sub-contractors to use BIM as an integrated tool for their construction project. In the Middle East, BIM is still regarded as a luxury software which is only used by experienced professionals and contractors. In Saudi Arabia, the civil engineers and construction engineers are the major construction industry professionals, who are controlling the construction market in the country. As a result of this scenario, a discriminative distribution of BIM has been among different construction industry professionals while support from all professionals is required for a successful and cost-effective project completion (Sodangi *et al.*, 2017).

### **3.9.1 Survey Results Regarding BIM Adoption in the Middle East Region**

The survey findings and conclusions from BuildingSMART (2011) are listed below:-

1. Contractors were the major users of BIM, while construction consultants used BIM for construction project design.
2. Within the construction sector in the Middle East, BIM adoption was highest amongst the developers.
3. Overall BIM adoption in Middle East was relatively low compared with North America and Western Europe.
4. Nearly 54% of construction professionals did not use BIM.
5. Nearly 21% of the participants in the BuildingSMART survey were not aware of BIM and so were unable to complete the survey regarding the adoption and awareness of BIM in the Middle East.
6. Nearly 25% of the participants reported that they used BIM for their own purpose.
7. In the Middle East, the adoption of BIM was still at beginner level and they were using BIM for graphical visualisation of the project
8. Awareness regarding BIM was very high in Middle East region and nearly 79% of

the respondents had a high regard of BIM benefits

9. BIM adoption needs to be mandated and encouraged by the governments in Middle East countries.
10. General capabilities and training programmes regarding BIM usage should be promoted and taken by the construction industry professionals.
11. BIM education and occupation knowledge regarding BIM needs to be initiated in the academic curriculum in Middle East region.

Thus, the main finding from this survey was that the BIM adoption level was very low in Middle East countries, considering the BIM adoption percentages of North America and Western Europe.

### **3.9.2 Survey Results Regarding Barriers to BIM Adoption in the Middle East Region**

According to the survey findings from BuildingSMART (2011), in the Middle East the main barriers to BIM adoption are as follows: -

1. Lack of experienced and skilled staff who are knowledgeable and equipped to use BIM.
2. Cost of BIM implementation.
3. Lack of education and lack of proper training in using BIM.
4. Nearly half of the respondents mentioned that they had a very low level of knowledge and understanding about BIM usage, and their learning and knowledge were self-learned.

As far as the Saudi Construction Industry is concerned, BIM technology is still in its immature stage, while the level of awareness is emerging in Saudi Arabia. Kazi (2005), states that due to the lack of already trained professionals and the lack of professional training, most of the construction companies and contractors are not using this relatively new technology in their projects. Moreover, another important fact which is acting as a key barrier to BIM adoption is the negligence and unwillingness to adopt new technology, an attitude found among the construction industry professionals and clients.

However, the BuildingSmart (2011) survey omits to mention that the public sector in Middle Eastern countries is not taking any steps towards mandating the use of BIM at least for public projects. In addition, it fails to point out that there is a dire need for BIM guidelines, standards and manuals as well as a government department, taskforce or a national BIM alliance in order to develop a national BIM training programme for both governmental and



industry groups in the Middle Eastern countries that were surveyed.

### **3.9.3 Discussion of BIM Survey Results with Regards to Saudi Arabia**

Although the benefits of BIM can be monetized in terms of cost-effectiveness and time-effectiveness in completion the construction project, it is proving difficult to inform people about such benefits of BIM in Saudi Arabia. Furthermore, there is no structured initiative from the leaders of the construction industry or the government of Saudi Arabia in using BIM for construction projects. However, some private sector construction organizations have taken initiatives and incentives in order to promote the use of BIM in Saudi Arabia, and construction professionals are expecting an emerging future for BIM in the Saudi Arabian construction industry.

Moving far from the conventional 2D CAD program and paper-based practices to BIM and the strategy for sharing a 3D visual models has tremendous advantages. Nevertheless, there could be a few barriers or challenges that may influence the implementation of BIM within construction organizations in Saudi Arabia. Therefore, in light of the above, this study is researching why such a valuable instrument is not generally utilized as a part of the construction industry in the Kingdom of Saudi Arabia, what the barriers are to this, and what strategic procedures can be actualized for the most effective adoption and acceptance of BIM.

### **3.10 BARRIERS TO IMPLEMENTING BIM IN THE KINGDOM OF SAUDI ARABIA**

The successful implementation and acceptance of BIM technology by the construction industry in KSA is intended to be an abandonment of previous methodologies characterized by the physical movement of paper-based designs and written communication from government officials (Azhar, 2011). With the BIM platform, this methodology will have to be abandoned and replaced by correspondence through software collaboration tools. The hesitance in adopting the new technological options of collaboration may hamper the successful implementation of BIM in Saudi Arabia, regardless of the capital outlay and sophisticated level of the applications (Sodangi *et al.*, 2017).

Secondly, the implementation of BIM in Saudi Arabia's construction projects may be slowed down by the technical capabilities of the professionals who are required to participate actively on the BIM platform (Ikediashi *et al.*, 2014). It is expected that government officials, appointed contractors and designers will need vast amounts of information about the applications

available through BIM. Failure to engage technically competent users in BIM would be detrimental to any such project as then it would not yield the intended efficiency.

### **3.11 TOWARDS IMPLEMENTING BIM SUCCESSFULLY IN THE KINGDOM OF SAUDI ARABIA**

The successful implementation of BIM requires not only a top-down implementation strategy but a bottom-up one too, which regulates the working practices of the construction industry as a whole and facilitates the smooth flow of information into and from a BIM database (Vass and Gustavsson, 2017). This requires appropriate planning, patience and the full commitment of all stakeholders. The initial phase of BIM implementation concerns the establishment of a work schedule through an action plan. The plan ensures that implementation will remain on track throughout the project life cycle. The planning phase concentrates on collecting pertinent information regarding the present techniques, the procedures and the technical capabilities of the customer. Ascertaining the prevailing conditions can help the relevant organization or government department understand the technical, professional and economic capabilities required (Krygiel *et al.*, 2010). Once these parameters have been established, the next phase is implementation.

Effective implementation of technological innovation in construction requires an understanding of the complexity underpinning the process as it is essential for construction organizations to plan and control the implementation of any innovative concept within controlled budgets and time scales (Motawa *et al.*, 2004). The transition to BIM depicts a major move towards a new CAD workflow platform, which requires the reorganization of employees according to the changes in their roles. The most notable change is the redefinition of the drafters' roles. In some instances, it may become necessary to replace the current staff with those who are BIM-competent.

Training regarding BIM application and implementation among the stakeholders and staff is another critical aspect to consider while planning for BIM implementation. This is in light of the new concepts introduced by BIM in comparison to a conventional CAD workflow. The training entails preparing the users with the knowledge and capacity to facilitate the smooth flow of information to and from the BIM database.

Thus, for BIM to work successfully in KSA, based on the comprehensive literature review carried out for this research the following key aspects have to be made to work:

- BIM awareness
- IT requirements
- Training of construction staff and stakeholders
- Working culture shift in the construction industry

### **3.12 IMPACT OF LITERATURE REVIEW ON THE AIM AND OBJECTIVES OF THE RESEARCH**

In order to conduct this research in the field of BIM, a comprehensive literature review was required, and therefore this chapter conducted a literature review on an introduction to Building Information Modelling (BIM). Though the main purpose of this research is to find out the current situation of BIM, awareness regarding BIM adoption and implementation in the construction industry of KSA, and barriers of BIM implementation in KSA, a basic understanding and background of BIM implementation and usage help the researcher to understand the situation. The basic concepts of BIM in the construction industry, along with the digital illustration and representation of BIM and the evolution of its different stages have been evaluated throughout the literature review. Then the benefits and challenges of BIM implementation were critically reviewed to understand the context of the Kingdom of Saudi Arabia.

Overall, this literature review aimed to provide an understanding of the research context about BIM and to help the researcher to meet the research aim throughout this study. Accordingly, some small changes have been made to the original research aim and objectives: the aim has been rewritten and shortened and more research objectives have been added after the literature review had been completed, with the intention of improving the research so it is clear and unambiguous, and making the research aim and objectives more concise and streamlined. Furthermore, the data collection from the research design perspective has two stages. The first is essentially concerned with collecting information and data concurrently from Saudi construction industry personnel by the use of a questionnaire survey and semi-structured interview questions. The statistical software SPSS was used to conduct the descriptive and inferential statistical analyses from the questionnaire, whilst interview data were analysed using the thematic content analysis method. The second stage of the research design was to further develop a framework for BIM implementation in the construction industry of Saudi Arabia based on the findings of the research and the analyses. This data collection method is similar to but not the same as the research work carried out by

Al-Shehri (2012), who made use of interviews as the main method for collecting data and then subsequently conducted a questionnaire survey to validate the findings and generate recommendations.

### **3.13 SUMMARY OF CHAPTER THREE**

BIM is considered to be a feasible solution for project planning as it makes defining, analysing and annotating the plans and designs more practical and ensures design compliance with the appropriate engineering standards. At the same time, BIM allows modelling to take place through real-time examination, and enables designer feedback, all of which expedites the design procedure and reduces the likelihood of problems. Furthermore, a good perception of the subassemblies with their various purposes enables the competent construction of precise, construction-complete corridor models. In other words, using points, shapes, links, codes, road models and target parameters that can be tailored to the specific requirements of a design, will mechanize several repetitive and complex design and sustainability responsibilities, such as labelling and updating cross section sheets. Therefore, an understanding of the core components and techniques that are utilized when modelling with BIM is critical. BIM provides appropriate information to ensure dynamic, criteria-founded design. Ultimately, the key issues which have been identified in this literature review need to be further reviewed in the primary research phase of the project in order to gain additional updated knowledge on the Saudi Arabian construction industry. Conducting interviews with professionals on real world projects should help to achieve the aims and objectives of this research and consequently reach a conclusion on the hypothesis regarding the use of BIM in Saudi Arabia.

# **CHAPTER FOUR**

## **RESEARCH METHODOLOGY**

### **4.1 INTRODUCTION TO CHAPTER FOUR**

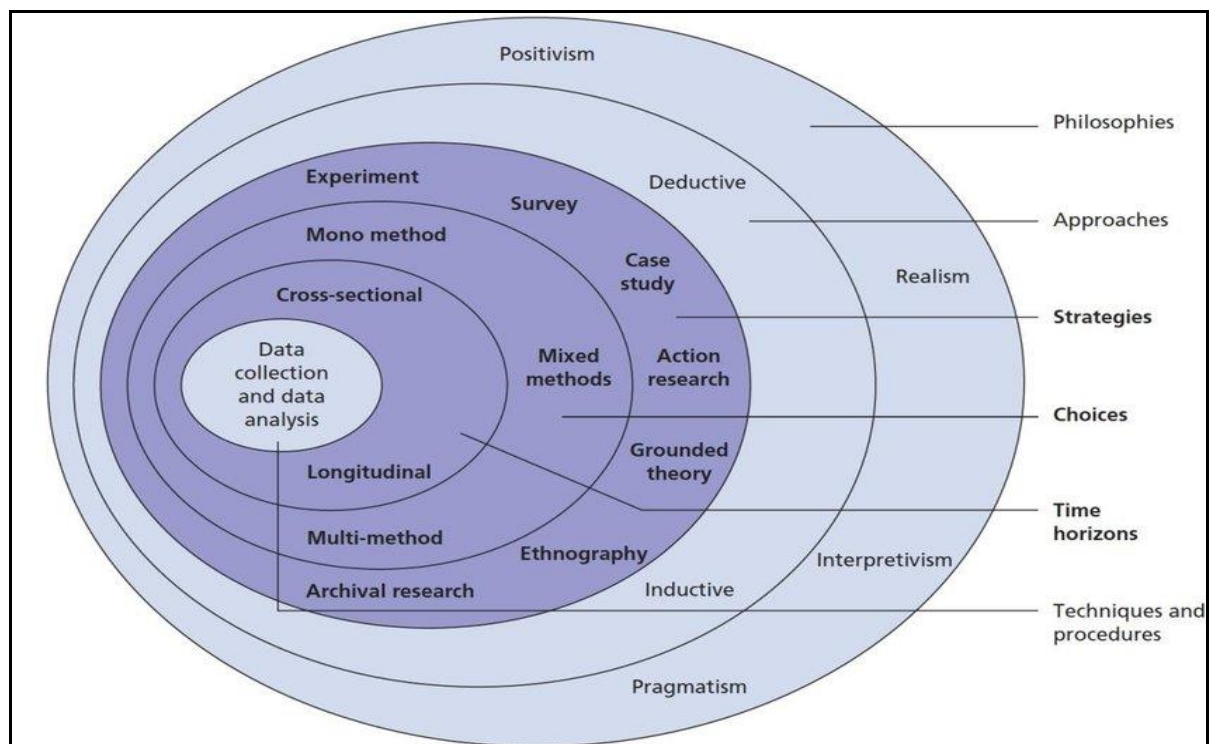
After a review of the relevant literature in the preceding chapters, it becomes necessary to design a suitable strategy for the collection and analysis of the data in order to achieve the aim of the research. Doing this requires a demonstration of research principles and the way they impact the design for addressing the research objectives. Thus, this chapter discusses the methods and methodologies used for the research. The chapter first describes how different kinds of approaches were used to select suitable methods through which the research would be conducted. The chapter goes on to explain the adoption of the research strategy, the population involved in the research, the sampling of participants, and issues of ethics in research and the way these were addressed. In the last part of the chapter, the methods for obtaining the data are discussed, along with the techniques used for the data analysis.

### **4.2 RESEARCH METHODOLOGY**

This section presents the proposed methodological framework for the research, and explains which research methods were utilized to achieve each of the objectives of the study. According to Fellows (2015), the practical method used for the procedures and the principles for the operation of the scientific research are generally referred to as the research methodology. There is also a substantial body of knowledge concerning research principles, which describes the philosophical prospects, methods, designs and strategies. Bryman and Bell (2015), Creswell (2012), Saunders *et al.*, (2012) and Kagioglou *et al.*, (2000) exemplify different kinds of model for conducting social research, and writings by these authors were used to develop the research methodology.

Saunders *et al.*, (2012) have categorized research into six phases and have presented the model as a research onion as can be seen in Figure 4.1. They separated the research into categories incorporating approaches, strategies, philosophies, time horizons, choices, techniques and procedures, and each layer of the onion explains a more comprehensive phase of the research (Saunders *et al.*, 2012). This method offers an efficient progression from which the methodology of the research can be designed. Besides this, it provides a logical

description of the organization of the research as the strategy of the research and also gives an explanation in a theoretical way about the assumed issues used in the research design. Based on the work of authors, the philosophy phase was started by the researcher, who passed through each of the layers and continued till the layer in which final data collection methods are identified (Saunders *et al.*, 2012). It follows that selecting a method for collecting data for any piece of research should be based on research philosophy, approach and strategy.



**Figure 4.1: The Research Onion**  
(Source: Saunders *et al.*, 2012)

The research onion was found useful for this research due to its adaptability for almost any type of research methodology (Saunders *et al.*, 2012; Bryman and Bell, 2015). The remainder of this section discusses the different areas of the research onion, based on the goal of the current research, and showing how these influenced the methodology adopted for this research.

### 4.3 RESEARCH PHILOSOPHY

Many researchers regard research philosophy as a significant factor for supporting any kind of research. The purpose of the exploitation of the methodologies used in the research and the tools of research is for the study of the research problem. Fellows (2010) portrays the

research methodology as a method of understanding what is under investigation, with an emphasis on reliability of results, and thus it is important for the appropriate methods to be used which will deliver the right insights (Vanderstoep, 2009). The research methodology is important for research because it is the basic principle or philosophy which directs the research.

A research philosophy refers to the set of beliefs concerning the nature of the reality being investigated (Bryman, 2012). It is the underlying definition of the nature of knowledge. (Bryman and Bell, 2015). It is through the use of assumed issues in a research philosophy that the commencement of the justification and validation of the research is conducted (Flick, 2011). According to Creswell (2012), ‘Research Philosophy’ refers to the nature and progress of knowledge. For the purposes of this research, it is imperative to understand the nature of knowledge based on the subject being investigated. This helps in ensuring the best approach to achieve the aim of the research being pursued.

There are two traditional philosophies in relation to research, and these are positivism and interpretivism (Creswell, 2012). The choice of research philosophy is defined by the type of knowledge being investigated in the research project (May, 2011). As a result, understanding the researcher’s philosophy could be beneficial in the explanation of the matters assumed in the research procedures and the way in which they fit into the methodologies used in the research.

#### **4.3.1 Positivism**

Positivism regards science as constituting a collection of facts, with the role of theory restricted to the organization of these facts into a logically coherent system from which new facts can be deduced or predicted (Heather, 1996). Furthermore, positivism builds on advocating natural science methods as the only way to study the world (Arbnor and Bjerke, 2009), including the study of social science (Bryman and Bell, 2015). Bryman and Bell summarize the positivism principles as *the principle of phenomenalism*, the *principle of deductivism*, the *principle of inductivism*, and *objective research procedures* (Bryman and Bell, 2015). Saunders *et al.*, (2012) support these principles and explain that the positivist researcher would most likely deal with a social reality confirmed by senses, create hypotheses based on existing theory, and then test those hypotheses using statistical analysis that leads to “law-like generalizations”. Saunders *et al.*, (2012), also mention that positivism advocates objective research processes. This objectivity can be regarded as an advantage of positivism.

Besides, positivism usually leads to a highly structured methodology and standardized observations to facilitate replication (Gill and Johansson, 2010). As some scholars (e.g. Hogan and Sinclair, 1996) argue, the replication possibility is an advantage of positivism that allows the validity of the research findings to be checked (Gill and Johansson, 2010).

According to Brand (2009), the system of belief which arises from the practices in the natural sciences assumes that issues which are the subject of research are likely to be studied objectively and so their reliability can be recognized with a practical degree of certainty. This way of thinking is referred to as positivism and is consistent with the thoughts from Saunders *et al.*, (2012), where it is plausible to investigate the social sciences in a corresponding way to that of natural science: in other words, the views and opinions of the researcher are eliminated in the research, so it is also referred to as a value-free way.

#### **4.3.2 Interpretivism**

According to Bryman and Bell (2015), interpretivism is an alternative to positivism. They explain that the study of people and their institutions is different from natural science and demands a kind of logic to explain the distinctiveness of human beings. Interpretivism argues that the social worlds of business and management are more complex to put them in generalized principles like physical science. Interpretation is shaped according to the researcher's set of meanings that he or she gives to the world. Furthermore, some authors claim that the interpretivism perspective is most appropriate in social science research (Saunders *et al.*, 2012), and it is often related to qualitative research (Bryman and Bell 2015).

However, in comparison to positivism, interpretivism considers idealism and relativist positions in relation to ontological and epistemological conventions. Reality is viewed by interpretivism as socially built (Saunders *et al.*, 2012) and hence is also referred to as social constructivism. The interpretivist view is that people determine reality and it is not generally obtained from external or objective factors (Easterby-Smith *et al.*, 2002). The interpretations of people will affect their actions when they put themselves in distressed situations. According to social constructivism, people use disparate constructions and interpretations, based on their experience, due to their interaction with the environment through which situations are analysed and interpreted (Saunders *et al.*, 2012; Easterby-Smith *et al.*, 2002).

Moving forward in this research, it was necessary to determine which perspective, interpretivism or positivism, would help to investigate the adoption and implementation of BIM within the Saudi Arabian construction industry. The nature of the subject, however,



presents both objective and subjective approaches. Whereas the idea of BIM as a game changer can be objectively deduced based on its impact, there is subjectivity regarding the advantages of BIM and the likelihood of it being implemented in the Saudi construction industry. This subjectivity relates to the knowledge that people have of BIM and their experience with the technology, as well as their level of understanding on how collaborative working in the industry can lead to better outcomes.

### **4.3.3 Choice of Research Philosophy**

Saunders *et al.*, (2012), suggest that ontology and epistemology influence the choice of research philosophy, due to their impacts on the researcher who is thinking about the procedures of the research (Saunders *et al.*, 2012). Ontology refers to the nature of knowledge and reality, whereas the concept of knowledge is defined as epistemology and the relationship between the researcher and his justified belief. These two factors are discussed below in relation to how they influence the philosophy adopted, which ultimately decides the methodology for researching the adoption and implementation of BIM in the construction industry of the Saudi Arabia.

#### **4.3.3.1 Ontology**

As mentioned above, ontology refers to the nature of knowledge and reality. Two main ontological frameworks were identified to influence the process of the research: positivism and interpretivism (Monette *et al.*, 2005). Furthermore, these frameworks can differ in description, such as referring to them as constructionism and empiricism, but in general the basic assumptions are very similar (Bryman, 2015). There is also an assumption in positivism that reality exists independently from the issue being investigated. Generally, it means that the concept of phenomena is consistent between subjects (Newman, 1998), and for that reason, there is a single reality for understanding the nature of knowledge (of a phenomenon). Conversely, according to interpretivism, the inherent meaning of social phenomena is created by each observer or group (Östlund *et al.*, 2011), leading to multiple realities. In this philosophy, one can never presume that what is observed is interpreted in the same way between participants and the key approach is to examine differences and nuances in the respondents' understanding.

Although there is a difference between the two approaches, there is no assurance that they form an intrinsic belief by the researcher which is then executed in all contexts of the research. According to Podsakoff *et al.*, (2012), no one philosophy is integrally better than

another even though a researcher chooses one over the other. Thus, the philosophy purely specifies the reasoning and validation of the research methodology.

#### **4.3.3.2 Epistemology**

The nature and concept of knowledge which is considered suitable in any specific field of study of knowledge is defined as epistemology (Bryman, 2012). Since it is closely associated with ontology and its assumptions of reality, epistemology considers views about the most appropriate ways of enquiring into the nature of the world (Easterby-Smith, Thorpe and Jackson, 2008) and provides a definition of knowledge and sources as well as the limitations of knowledge (Eriksson and Kovalainen, 2008). According to Collis and Hussey (2003), epistemology deals with the matters which the researcher accepts as or considers to be valid, consistent knowledge and their impacts on the research approaches.

Questions of epistemology begin to consider the research method, and Eriksson and Kovalainen (2008), go on to discuss how epistemology defines how knowledge can be produced and argued for. The researcher's stances on epistemology and ontology ultimately lead to the choice of research philosophy. The epistemological position of the researcher therefore determines how he goes about collecting data and interpreting what is gained. Within epistemology, there can be a "resources", or "feelings" orientated researcher. The resources-orientated researcher would typically embrace a positivist position while developing knowledge, whereas the latter would possess an interpretive perspective (Saunders *et al.*, 2012). This leads to the embracing of the positivist position by the resource-oriented researcher during the development of knowledge.

Positivism in the context of social research would indicate the researcher would make generalizations based on observable social reality (Bryman, 2012). Realism, much on the lines of positivism, holds that reality exists independent of the human mind (Bryman and Bell, 2015). Interpretivism stems from the phenomenological perspective that requires researchers to take a different approach to humans unlike studying objects like phones or cars according to interpretivism, which is known as the phenomenological perspective (Bryman and Bell, 2015). This position leads to the concept of a single reality and suggests that the phenomenon can be modelled and represented with numbers. For the interpretivist or feelings-oriented researcher, therefore, the approach to gaining knowledge requires the subjective views of the participants within the phenomenon being researched. Thus, the

researcher should then take an empathetic stance to comprehend the subjects from their own viewpoint (Saunders *et al.*, 2012).

The choice between the epistemological positions influences the approaches taken to collect and interpret data. For this research on BIM implementation in Saudi Arabia, the epistemological considerations were to determine two considerations: whether the subject being investigated would require different perspectives from the participants; or whether there was a need to assume that all participants would view the phenomenon of BIM adoption and implementation in the same way. Making a choice between the two perspectives required an understanding of the concept of BIM and a reasonable level of knowledge of BIM implementation.

#### 4.3.3.3 Methodology and Axiology

Methodology elucidates the methods used during the research and the rationales behind the processes, such as inductive or deductive methodologies, and these are defined by the experience of researchers in the collection and analysis of the information (Denzin and Lincoln, 2011). These methods are influenced by the philosophical stance adopted by the researcher (Refer to 4.3.3.1 and 4.3.3.2 above). Whereas interpretivism leads to a more deductive approach to research, positivism, on the other hand, leads to an inductive search for knowledge. These approaches have led to the two traditional methods adopted for data collection and analysis: qualitative and quantitative methodologies (Yin, 2013; Creswell, 2012; Denzin and Lincoln, 2011; Lincoln, Lynham and Guba, 2011; Mertens, 2010). The different methodologies are discussed in Section 4.4.

Table 4.1 presents a summary of the different philosophical stances and their associated methodologies.

**Table 4.1: Properties of Two Main Research Paradigms**

<div>Paradigm</div> <div>Component</div>	Positivism	Interpretivism
Ontology	Veracity (truthfulness) is exceptional. Reality exists before any investigation.	Multiple truths may be constructed, based on the outlook of study. Reality emerges during the investigation.

<b>Epistemology</b>	Signifies decision. Events are divided into sub-units. The distance between the investigator and investigated is maintained.	Signifies interpretation. Events are studied as a whole. Keeps interactivity between the investigator and the investigated.
<b>Methodology</b>	Quantitative methods often employed.	Employment of qualitative methods

(Source: adapted from: Yin, 2013; Creswell, 2012)

From Table 4.1 above, it can be seen that the two different philosophies lead to different approaches which can be pursued in research and hence for investigating the adoption and implementation of BIM.

#### **4.4 RESEARCH APPROACH**

The deductive approach and inductive approach are both used in research work. Easterby-Smith *et al.*, (2002) elucidate that positivist research is more inclined towards a deductive approach, whereas interpretivist research favours the inductive one. As mentioned, these approaches have also led to the two traditional methodologies: quantitative methodology, which is aligned more with positivism, and qualitative methodology, which is more associated with interpretivism.

##### **4.4.1 Deductive Approach**

The approach in which the established theory is modified into a hypothesis and formulated in the research approach for its testing is referred to as the deductive approach (Silverman, 2013). Such an approach is suitable in a situation where examination of the research project is related to the observed phenomena which fit the appropriate anticipations from earlier research (Wiles *et al.*, 2011). Hence, the deductive approach could be regarded as suitable for the positivist approach, which allows the preparation of theories and the statistical testing of anticipated outcomes to an acknowledged level of possibility (Snieder and Lerner, 2009). The deductive approach is characterized as the development from general to particular: the general theory and knowledge base is first established and the specific knowledge gained from the research process is then tested against it (Kothari, 2004). Thus, the deductive approach is linked to quantitative methodology.

According to Kerlinger and Lee (2000), there has been a domination of quantitative research approach for the last four to five decades. According to the positivist view of knowledge, quantitative methodology insinuates that there is one truth or a single objective reality in the world, which is influenced by unquestionable natural laws, and which does not relate to the human perception (Creswell, 2012).

This single objective reality is deterministic, which signifies a cause and effect relationship in social problem (Creswell, 2012). Activists of the quantitative research approach use coherent methods which incorporate several numerical measurements of observation and confirmation of hypothesis and laws which rule the single objective reality in the world (Clarke and Dawson, 1999). The research problems are translated into quantitative data in numbers and figures which clearly analyse the research issue (Hair, *et al.*, 2005). The quantitative approach, otherwise known as the scientific method or fixed design approach (Anastas and MacDonald, 1994, cited in Robson 2002), is obtained on the assumption that there is a single reality which is the objective.

According to epistemology, the quantitative research approach is advocated due to its adherence to an objective position in research, which insinuates that researchers must detach themselves from the object of the research (Neuman, 2006). Such a position is in accordance with the need to avoid biases and subjectivity in the process of inquiry (Creswell, 2012).

In accordance with the above discussion, therefore, the social or human problem is examined through the quantitative approach in relation to the social science which depends on theoretical assumptions relating to the gathering and analysis of practical data in order to determine whether the extrapolative generalization of the hypothesis is valid or not (Abdulai, 2007; Creswell, 2012). Hence, the characterization of quantitative research is as follows:

- In order to achieve the objective, the researcher remains detached and autonomous from the sample to achieve an objective and unbiased assessment of the situation.
- It uses a deductive form of logical reasoning, such that concepts, variables and hypothesis are chosen and maintained from the beginning to the end of the study.
- It generally utilizes packages of statistics for conducting descriptive and deductive numerical analysis of the data, to test the reliability and validity of the results.
- The direction of the research is provided by the literature review. In accordance with this, a framework is developed and data is collected and analysed for the purpose of testing the validity or generalization of the framework.

#### **4.4.2 Inductive Approach**

The inductive approach is characterized as one that moves from the particular to the general (Bryman and Bell, 2015). In this method, the beginning point is considered as observations for the researcher, and patterns are observed in the data (Beiske, 2007). In the inductive approach, there is no framework which usually advises how the data collection will take place, and the focus of the research can then be developed after the collection of data (Flick, 2011). Despite a generation of new theories, it is also accepted that as the data is analysed it may be observed as suitable for an existing established theory (Bryman and Bell, 2015).

Such a method is basically used in qualitative research, in conditions where there is no theory for notifying the research process, which may be of advantage as it reduces the potential for researcher bias in the data collection stage (Bryman and Bell, 2015). The interviews are conducted in association with particular phenomena and then the information can be investigated for patterns among respondents (Flick, 2011). However, such a method could also be used effectively within positivism methodologies, in which analysis of data produces the most important patterns which are used to notify the production of outcomes.

The qualitative research approach entails inductive orientation as well as an exploration of comprehensive social and human challenges where information is collected from the participants in their natural environment by the use of evolving flexible queries and the process involved (Creswell, 2012). However, there are many designs, such as ethnography, phenomenology, grounded theory, narrative and case study (Creswell, 2012).

- Investigation of an intact cultural group is studied in its natural environment over a longer period of time, based upon ethnography (Flick, 2006; Creswell, 2012), where a collection of data is achieved through questioning and observations.
- For the formation of a general abstract theory, the processes, design and interactions or actions are grounded in the perspective of members in grounded theory (Creswell, 2012), where collected data are refined in several stages. There is also the identification of resemblances, disparities, and interrelationships of data for the formation of grounded theory (Neuman, 2006).
- A profound study and analysis of process, activity, event or people over a period of time, according to case studies (Yin, 2013).

The study of phenomena based on human experiences and their exemplification (Gomm, 2008) for the formation of meaningful patterns about that phenomenon is referred as phenomenological design. Further, there is a study of the life of several individuals by the researcher according to narrative research. Then, data are collected from the people about their lives and those data are organized in a systematic manner so that both narrators' and researchers' opinions are meaningful (Creswell, 2012).

#### **4.4.3 The Mixed Methods (Pragmatic) Approach**

Some researchers are of the view that the traditional approaches which lead to either qualitative or quantitative research methods may not always be appropriate for a given research (Glasgow, 2013; Onwuegbuzie, and Leech, 2005; Maxcy, 2003). There are instances in which the researcher may need to combine aspects of the two traditional approaches in order to ensure that the research objectives are achieved. This leads to the concept of mixed methods. This approach stems from a pragmatic perspective, which suggests that positivism and interpretivism are not opposing views, but rather represent the two ends of a continuum (Glasgow, 2013; Feilzer, 2010; Creswell, 2012; Amos and Pearce, 2008; Denscombe, 2007).

As presented by Creswell, the fresh approach of research generally known as multi-methodology is an approach with mixed methods (Creswell, 2012). The motivation for this realistic position is that the truth only works at a specific point of time and it is important for the researcher to focus on the social issue, and in addition, gather every single required philosophy, as well as the necessary methods and tools, for addressing the problem (Collins *et al.*, 2006).

A mixed design approach may also be used in research (Robson, 2002), as it makes use of two or more methods, and could yield both quantitative and qualitative data. The quantitative research method gathers information for comparison with one another. The use of such methods is reasonable for developing quantifiable and comprehensible outcomes (Bell, 2009). Thus, one of the techniques of data collection that is regarded as significant is the quantitative method. Further, the collection and analysis of quantitative data are done through other common methods which involve statistics and survey techniques.

The use also of the qualitative method helps in filling the void formed by quantitative research which gives importance to numbers, statistics and percentages. In comparison to quantitative methods, qualitative investigations are not focused on the quantification of data, but give importance to the comprehension of individual views about the world (Bell, 2009).

The determination of relationships, categories and assumptions for notifying the participant's perspective of the world is the main objective of the analysis of qualitative information (Basit, 2003).

Whereas the positivism and interpretivism stances align with quantitative and qualitative research respectively, the pragmatic stance aligns with a mixed methodology where both quantitative and qualitative methods can be adopted for a single study to investigate different aspects of the phenomenon.

Many researchers praise the mixed-method approach. Johnson and Turner (2003), for example, defined their 'fundamental principle of mixed methods research' in which 'methods should be mixed in a way that has complementary strengths and non-overlapping weakness. The advantages of the mixed method are the ability to answer questions that other methodologies cannot, and the opportunity for presenting a greater variety of opinions (Johnson and Turner (2003). Most importantly, such an approach is a mixture of qualitative research and quantitative research. Many researchers are of the view that a prudent combination of quantitative and qualitative approaches can include the strengths of both methods (Creswell, 2012; Felizer, 2010; Maxcy, 2003; Jackson and Mead Niblo, 1999).

Chynoweth (2009) states that academic inter-discipline and working practices within the construction industry are based on relationships and multi-disciplinary processes. Therefore research in BIM is particularly applicable, as it is an associated set of working processes and procedures facilitated with the application of modelling technologies (Eastman *et al.*, 2011).

Fellows and Liu (2008) state that understanding research in the built environment is better facilitated through the application of mixed methods which can determine the perspectives of the participants in the research process. This is important from a BIM perspective because BIM brings together participants in a collaborative, cooperative and proactive manner through a common source of information (Outreach, 2012) in order to create new knowledge through a more practical research approach that can facilitate the implementation of BIM processes and technology within construction organisations.

#### **4.5 THE SELECTED RESEARCH DESIGN FOR INVESTIGATING THE ADOPTION AND IMPLEMENTATION OF BIM IN THE SAUDI ARABIAN CONSTRUCTION INDUSTRY**

From the discussions carried out in Sections 4.3 and 4.4, an appropriate design has been adopted for this research. Denzin and Lincoln (2011) suggest that design in research provides



the directions for linking the elements of the methodology adopted for an investigation in association with the model to the strategy of the research, and then linking the strategy to the approaches for the collection of pragmatic data. Based on this, Creswell (2012) advises that the research design should link the research questions, the data collected and the results. After the review of research philosophies and approaches, this section presents the design adopted for this research and provides a justification for how it can help to ensure this research leads to reliable results.

#### **4.5.1 Philosophical Stance**

According to Creswell (2012), for any investigative research whose main objective is to find the factors or variables which impacts the result of determining the causes, the positivist approach is adequate. Since the goal of the current research is to study the extent of the use of BIM and to identify the barriers to it in the Kingdom of Saudi Arabia, which has an impact on the results of construction project delivery, this study has adopted a positivist paradigm to underpin the research. As one of the major goals of using positivism in the present research is to obtain valid and reliable knowledge as a set of universal principles that can explain, predict and control human behaviour across the target sample. Thus, the positivist researcher takes a controlled and structural approach to conducting research by initially identifying a research topic, constructing appropriate research questions, adopting a suitable research approach, collecting data, and analysing and interpreting the relationships between the variables (Denzin and Lincoln, 2011).

Henceforth whilst the literature is prevalent with the many uses of BIM in the global construction industry, there is little or no empirical evidences of investigating the uses of BIM in Saudi construction organizations. This suggests that the identified relationships may not be exhaustive enough or some do not actually exist, as such, there is need for exploration to fully ascertain the relationships. This realization has led to the need for an interpretivist look at the implementation of BIM in Saudi Arabia, as the level of adoption is likely to be related to the subjective views of the parties within the construction industry which are expected to adopt BIM.

As discussed in 4.4.3, there are instances where a researcher may combine different perspectives or rational opinions based on the nature of the problem to be studied (Creswell, 2012; Felizer, 2010). There was a need, therefore, to test for the knowledge and benefits of BIM in Saudi Arabia based on what has been studied elsewhere, and to do this through a

quantitative approach, yet at the same time to use a qualitative approach to gather views on the factors and contexts specific to Saudi Arabia that may influence the kingdom's adoption and implementation of BIM. This research, therefore, has adopted a pragmatic view, taking advantage of both positivism and interpretivism (Creswell, 2012).

#### **4.5.2 Research Approaches**

In order to find the appropriate study approach, different approaches are used, such as deductive and inductive research, which are developed from epistemological or theory applications, as well as the type of questions asked by the researchers. Considering the epistemological positions discussed in Section 4.3 as well as the research questions presented in Chapter 1, this research has taken a mixed approach to the study, which aligns with the deductive approach was taken to investigate the Saudi Arabian construction industry, in terms of the extent of the use of BIM, its functionalities and improved project performance, and the challenges of implementing BIM in Saudi Arabia, as it starts from more generalizations to more specific.

As the research study investigates the extent of the use of BIM and identification of the barriers to it in the Kingdom of Saudi Arabia, the quantitative approach has been used in order to provide a clear insight into the study. As presented in Saunders *et al.*, (2012), the deductive method can be used to answer queries relating to who, what, when, where, how, how much, and how many. For instance, it helped in answering the research question "What is the level of awareness on BIM in the Saudi construction industry?".

On the other hand, some aspects of the research demanded an inductive approach, so as to be able to understand the reason for the current level of adoption of BIM within the Saudi Arabian construction industry and how this could be improved. This required the use of qualitative approaches which were aligned with the interpretivist perspective. As Yin (2013) suggests, the qualitative approach helps to answer questions about 'how' and 'why' by delving deeper into the issues being investigated. This helps to bring different views (multiple realities) of the problem, thus enabling a better comprehension of the issues. For instance, it helped in finding the strategies to adopt in answering to the research question "How could BIM be adopted more in the Saudi construction industry?".

This research, therefore, took a varied methodological approach uniting aspects of both qualitative and quantitative research.

## **4.6 RESEARCH METHODS**

After deciding the approach to be adopted, the researcher was faced with different options of methods based on the approach adopted. Research methods were selected to provide the types of collection of information, analysis and interpretation for developing the results of the research. Saunders *et al.*, (2012) suggest that research methods are ‘research strategies’ or the tools employed to conduct the research. These include experiments, surveys, case studies, and interviews (Saunders *et al.*, 2012). According to Moody (2007), the success of any study depends on the methods selected to gather data. Each method presents a set of pros and cons which are related to the research approach adopted. The survey research method is known to be especially applicable where opinions relating to facts are sought (Descombe, 2007). Interviews, on the other hand, are used to gather in-depth information on a phenomenon, while case studies are adopted when a phenomenon is to be studied in its real-life context (Cohen *et al.*, 2000; Yin, 2013).

As this research took a pragmatic approach by making use of both quantitative and qualitative methods, different methods were adopted, with the main two being a survey by means of questionnaires, and interviews, as discussed below.

### **4.6.1 Questionnaire Survey**

A questionnaire survey was undertaken as according to Denscombe, (2007), this allows to determine information such as opinions and perspectives from the participants in addition, to answering “Who”, “What”, “Where”, “How many”, and “How much” types of questions.

One of the cheapest and simplest ways of gathering a large amount of quantitative information is through a questionnaire. This can be given to any individual at any time, and one does not need to investigate when the participants answer the questions. Questionnaires may be utilized in various ways such as by telephone, e-mail, internet, or face-to-face interview (De Vaus, 2002; Naoum, 2008). Cautiously structured questions, which are selected after careful consideration, can only be compiled after the literature review as the questions should be linked and correlate with the findings of the literature. The major objective of the questionnaire is to obtain reliable responses from a chosen sample, with the aim of finding out what a selected group of participants do, think or feel (Collis and Hussey, 2009).

Considering the strengths of this method, the questionnaire was used to gather facts on the extent of BIM adoption in Saudi Arabia, the level of knowledge of research participants, the

barriers to the adoption of BIM and its advantages. Gaining this information required the views of a good number of professionals in the industry to ensure a representative answer was gained.

Certain precautionary measures were taken when designing the questionnaires. The questions were designed in a way that would be comprehensible to the respondents. As McQueen and Knussen, (2012), emphasizes the questions must be clear and easily understood by the respondents. It should be easy to administer so that the recorded answers can be easily edited, coded and transferred onto a computer file for statistical analysis and its flow, length and structure must motivate respondents to complete the questionnaire.

#### **4.6.1.1 Design of the questionnaire**

A questionnaire may incorporate open-ended questions along with close-ended questions with a scheduled group of answers for the participants to select from (Fellows and Liu, 2009). Numerical responses can be obtained from the use of closed questions, thereby providing an opportunity to use descriptive or inferential statistical analysis, while the open-ended questions allow the researcher to review further and discover a richer meaning to the responses of the closed questions. The use of a questionnaire enabled primary data to be collected from construction professionals in Saudi Arabia regarding the level of awareness of BIM, views on advantages of BIM, functionalities of BIM, and their experiences with BIM, as well as to identify the obstacles to the use of BIM in the Saudi Arabian construction industry. Utmost care was taken to ensure that the questions were organized in a similar manner. For the purpose of this research the awareness of BIM equates to the “knowledge that something exists, or understanding of a situation or subject at the present time based on information or experience” as defined in the Cambridge Dictionary (2018).

The design of a good questionnaire is vital in achieving a successful response rate, as in the past the rate has been quite low, especially in the construction industry (Soetento 2006). In order to achieve this, a piloting process was first undertaken. The questionnaire was designed based on the research aim and objectives. The issues were also obtained from the literature review.

The questionnaire consists of 5 parts. The first part consists of ten questions which requested information on the background of the participants and their company (demographics). The second part focuses on the use of BIM in the Saudi Arabian construction industry and this consists of twelve questions. With the second part of the survey, the design of the questions

and the use of the Likert scale helped to ensure that the answer options provided variations for the respondents. For example, questions on the level of awareness and familiarity were designed to not just provide a yes or no answer, as according to Johns (2010) this greater flexibility provides the advantage of capturing different levels and views on the Likert scale. The answer options ranged between two extremes, from 'not aware/not familiar' to 'expert user'. Between these extremes, respondents were able to select their level of awareness from minimal familiarity to a high level of familiarity. The answer options were carefully chosen so as to be simple for respondents to understand and relate to. The third part focuses on the awareness and benefits of BIM in the construction industry of Saudi Arabia and consists of thirteen questions. Part 4 focuses on the barriers to adopting BIM in the Saudi construction industry and consists of ten questions, whilst part 5 focuses on the strategies for the greater adoption of BIM in the Saudi construction industry and consists of eleven questions.

The questionnaire was designed and written in English. However, most of the participants communicate in Arabic, and it was therefore translated into Arabic for some participants, so as to ensure that they fully understood the questions. To ensure that there was no loss in translation the questionnaire has been checked by translation services.

#### **4.6.2 Interviews**

An interview is an appropriate way of collecting weighty and in-depth information and views relevant to the issue being investigated (Denscombe, 2010). Participants were asked a range of designed questions by the interviewer in relation to the research in order to collect answers that would be relevant to the goal of the research (Bailey, 2007). A face-to-face interview is necessary where interpersonal contact is important for describing the situation, and so the information of the respondent is acknowledged (De Vaus, 2002). Adopting interviews as a method of data collection has several benefits. It provides an opportunity for better communication between the participant and the interviewer, providing better control of the process of the interview (Naoum 2008). Furthermore, there is also a higher chance of obtaining detailed and in depth information that is of high quality. Other advantages are in the accuracy of the answers, speed, and high response rate, flexibility to reframe the questions and give the researcher chance to seek further clarification of the issues and obtain more details (Naoum 2013).

There are three forms of interviews: unstructured, structured and semi-structured (Bailey, 2007). The unstructured interview corresponds to a conversation directly related to the

research where the interviewee is allowed to develop ideas and follow their sequence of thought, whereas in a structured interview, questions are provided to different interviewees in a similar order and in similar wording in a strictly controlled format of questions and answers (Silverman, 2003). In fact, it is like a questionnaire being used in a face-to-face interview (Denscombe, 2007). However, in a semi-structured interview, there is more flexibility with respect to the order in which questions are responded to. It also provides the respondents with the opportunity to form ideas and speak clearly about them. Therefore, semi-structured interviews were adopted in conducting the present research.

The adoption of interviews as a data collection method helped to gain further insight into the problem of BIM utilization and execution in the construction industry of Saudi Arabia. For such research, there was a need to understand why the level of BIM adoption and implementation is low in Saudi Arabia and how this could be improved. Such information required in-depth knowledge and analysis of the questions, and the semi-structured interview provided the best means to gather this information.

To gain the views and opinions of Saudi construction professionals, interviews were used to investigate the adoption of BIM in construction organizations in Saudi Arabia in terms of the benefits of BIM and the type of strategies that can be put in place for its implementation. The next section discusses how data was collected for this research, based on the chosen methods.

## **4.7 DATA COLLECTION**

Saunders *et al.*, (2012) regard the data collection and analysis as the most important aspect of the research undertaking. This is illustrated and explained in this section of the research.

### **4.7.1 Ethical Considerations**

It can be said that this is the most important aspect of field research (Bailey, 2007). Ethical considerations are crucial for protecting the participants as well as their organizations. They also improve the quality of research and can defend it from any impropriety (Creswell, 2012; Farrell, 2011).

Ethical issues were given great importance in conducting this research, in terms of the selected topic, data collection process and analysis. The research was carried out in such a manner that the confidentiality and integrity of participants were respected and valued. The objectives of the research were openly stated to the participants, and it was ensured that they were doing it on a voluntary basis. The participants were also assured that the data provided

by them would be destroyed at the end of the research. The questions were designed in such a manner that they were free from any threat or any kind of misguidance or deception. Prior to contacting any of the participants, ethical approval was obtained from Wolverhampton University's School of Architecture and Built Environment Ethics Committee.

#### **4.7.2 Sampling Types**

The method by which individuals from a group of people are selected to take part in the collection of data during the research is known as sampling (Saunders *et al.*, 2012). There are two methods of sampling for the purposes of research:

- Probability or representative sampling – whereby each sample has the chance of being selected randomly.
- Non-probability or judgmental sampling – whereby generalization is not significant, and each sample does not have the chance of being selected randomly.

##### **4.7.2.1 Probability Sampling**

There is a certain level of unpredictability in relation to the selection process when units are selected from the given population, and this is termed as probability sampling (Trochim, 2006). The chance of selecting any unit from the population is basically equivalent to the method employed (Saunders *et al.*, 2012). These methods are generally used in research strategies involving surveys when statistical implications are required for analysis of data such that outcomes may be regarded as representative of the population (Saunders *et al.*, 2012). Bryman and Bell (2015) assembled probability sampling into four different types:

- 1) Systematic Sampling
- 2) Simple Random Sampling
- 3) Multi-Stage Cluster Sampling
- 4) Stratified Random Sampling

##### **4.7.2.2 Non- Probability Sampling**

If the goal of the research requires an alternative way of choosing the sample, then non-probability sampling techniques are utilized (Saunders *et al.*, 2012). Saunders *et al.* (2012) explain that non-probability sampling consists of purpose sampling as one of the strategies. Such sampling is conducted when generalization is not significant, and it is not plausible to select a sample randomly. Bryman and Bell (2015) divide non-probability sampling into four different types:

- 1) Quota Sampling - Whereby the aim to represent the major characteristics of the population by sampling a proportional amount of each respondent. It is easier to organize and more reliable as compare to random sampling
- 2) Convenience Sampling - Whereby any subjects are selected because of their convenient accessibility and proximity to the researcher. They are not representative of the entire population.
- 3) Snowball Sampling - This is usually carried out when there is a very small population size. Whereby research participants recruit other participants for who also meets the criteria of the research. It is used where potential participants are hard to find for the study and allows for studies to take place where otherwise it might be impossible to conduct because of a lack of participants.
- 4) Purposive Sampling - The main objective of a purposive sample is to produce a sample that can be logically assumed to be representative of the population. This is often accomplished by applying expert knowledge of the population to select in a non-random manner a sample of elements that represents a cross-section of the population (Bryman and Bell 2015).

The procedure and design of sampling are very significant for the design of the research. As a result, in the context of this research ‘Probability Sampling’ using Simple Random Sampling is proposed to be used to select participants for the research. The reasoning for this is to target a large number of participants with the required skill set, so as to acquire a significant response that will enable swift and focal data collection.

For this research, a probabilistic sampling approach was adopted to collect quantitative data through the use of a questionnaire. This helped to ensure the data gathered was representative of the industry. For the purposes of the interview, however, a non-probabilistic sampling method was used where different professionals were purposely selected for the interview using purposive sampling approach.

#### **4.7.3 Quantitative Data Collection Through Questionnaires**

The quantitative data was collected using questionnaires. This section discusses the sampling technique found to be suitable in collecting the quantitative data; how the questionnaire was piloted and improved; the channels used in distributing the questionnaires; and the sampling size used in conducting the research.



#### **4.7.3.1 Sampling Technique Adopted**

Sampling is the technique by which units from a population are chosen to participate in the data collection phase of a research (Saunders *et al.*, 2009). Hence, for the context of this research, the simple random sampling technique was used to select the quantitative research participants. The reasoning for this was to target a large number of participants with the required skill set, so as to acquire a significant response to enable swift and focal data collection.

Considering the goals and the time constraints of this research, the sample population used for this survey were construction personnel working in construction organizations operating in Saudi Arabia. The research samples for the questionnaire were chosen randomly. The aim was to have an even distribution that would be representative of the population. Therefore, construction professionals were given a chance to participate in the study.

In order to reach out to all the construction professionals working in Saudi Arabia, the questionnaire was distributed through the government ministries, higher educational institutions and the Saudi council of engineers. All construction companies and professionals practicing in Saudi Arabia are registered with the council. Therefore, it is a very good channel of reaching out to the population. However, some professionals may be working in the higher educational institutions as lecturers or in the works department. These were also contacted directly, though may have already been reached through the council. Similarly, professionals working in the government ministries were contacted directly though they may have been reached already through the council.

#### **4.7.3.2 Questionnaire Piloting**

Initially, in order to ensure the adequacy of the questionnaire, a pilot exercise was carried out amongst a small number of respondents from the Saudi Arabian construction industry, so as to act as a rehearsal for the main questionnaire. This was to ensure that the research objectives were met, the questions were clear and unambiguous, and the length of the questionnaire would be appropriate, and to identify any significant topic omissions, and any questions that a respondent would feel uneasy about answering or commenting on (Creswell, 2009; Zikmund *et al.*, 2010). This would allow an accurate representation of the constructs of interest, and ensure the usefulness of the data (Roller, 2015). Then further to this, the pilot questionnaire, which included questions for pilot testing feedback and improving the questionnaire, was posted on the internet using an internet-based platform known as

‘surveymonkey.com’. This was utilized as web-based questionnaires are an alternative to the traditional methods of questionnaire distribution and data collection and are now frequently used for research studies.

The piloting respondents were asked for their opinion about the survey and to give a review on the layout of the questions, wording, and order. Through construction industry associations and professional bodies, the questionnaire was given to construction professionals and further personal contacts of the researcher within the construction industry of Saudi Arabia. The use of the industry associations helped to ensure that there was a reduction in any bias; a random sample was therefore obtained from the industry associations.

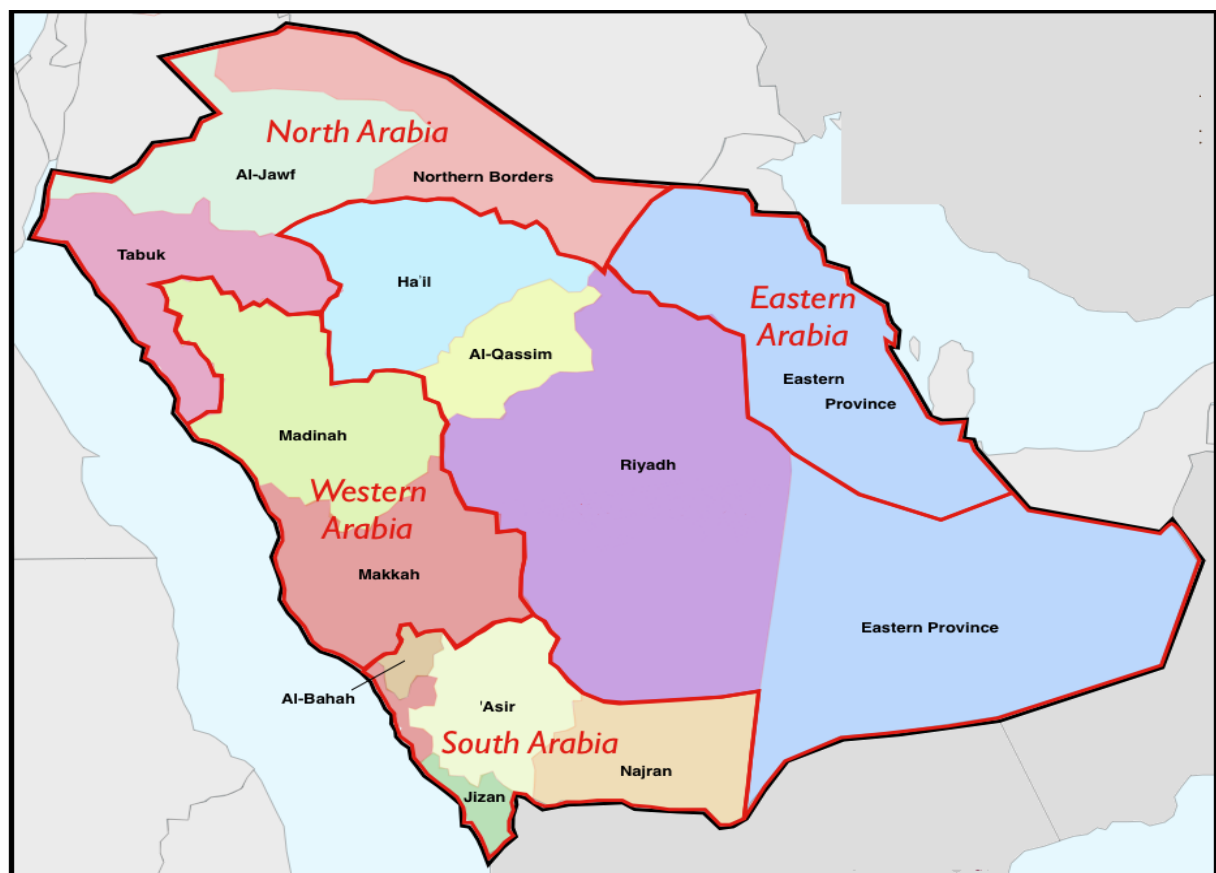
The respondents to the pilot survey included architects, project managers, construction managers and civil engineers, who checked that the questionnaire was adequate for relevance, length, clarity, conciseness, complexity and layout, and who had the opportunity to provide general feedback, stating their reasons. A total of 11 responses were obtained from the piloting process. Whereby simple random sampling was used to determine the degree of variation in the population studied, the population size and the desired margin of sampling error.

From the feedback provided by the responses to the pilot questionnaire, some of the comments and suggestions reported a completion time of about 50-60 minutes. Some respondents pointed out that some of questions were asking irrelevant and unnecessary information. It was also highlighted that some questions were too technical to answer. In particular, it was suggested that some questions were ambiguous, and the number of possible answers should be reduced. In addition to this it was suggested that the structure of the questionnaire could be improved by allowing room for comments to be made.

Subsequently refinements were made to improve the questionnaire survey. The questions seeking irrelevant and unnecessary information were completely removed, thus reducing the number of questions and making them short and to the point. For example, a question asking what is your specialization in construction projects was removed altogether from the questionnaire survey as it was considered irrelevant. The questions which were deemed to be too technical were removed altogether. Some answers were reduced in order to avoid any ambiguity. Likewise answer spaces were increased for all open-ended questions to allow for more written comments. Similarly, the length of the questionnaire was amended to reduce the time taken answer the questionnaire survey 50-60 minutes to take 30-45 minutes at most.

#### 4.7.3.3 Administering the Questionnaire

A request was published in the Saudi Council of Engineers Monthly Newsletter for Saudi Arabian construction professionals to complete the on-line questionnaire using the web based platform SurveyMonkey.Com. In addition to this, copies of the questionnaire were also distributed personally by hand out at live construction projects when site visits were conducted in the Riyadh Province, as well as the Eastern Province and Western Province of the Kingdom of Saudi Arabia. Figure 4.2 below illustrates the regions where live projects were visited. The data was collected between 27 April 2016 and 27 July 2016.



**Figure 4.2: The Provinces of the Kingdom of Saudi Arabia**

(Source: [sites.google.com/site/saudiarabiajj/country](https://sites.google.com/site/saudiarabiajj/country), 2017)

#### 4.7.3.4 Sampling Size

As discussed in Section 4.7.3.2, the questionnaires were distributed to Saudi construction professionals. This was achieved by sending both electronic and hardcopy questionnaires to them through the 3485 construction organizations registered with the Saudi Council of

Engineers; the works department in the 22 Saudi government ministries; and also through the 22 Saudi Colleges of Architecture and Engineering.

A total of 342 professionals responded to the questionnaire. Out of these 342 responses, a total of 224 (65.49%) questionnaires were fully completed as can be seen in Table 4.2 below. From these 224 responses, only 185 respondents are aware of BIM and involved in BIM practice. Therefore, 54% of the questionnaires were fully analysed, as these 185 respondents had fully completed all the sections including the awareness and benefits of BIM, and all the questions were specifically aimed at studying the awareness, benefits and strategies for BIM application. The method and procedures adopted for analysing the quantitative data collected is discussed in Section 4.8.1.

**Table 4.2: Total Responses for Each Method of Questionnaire Distribution**

<b>Data Collection Method</b>	<b>Number of respondents</b>	<b>Number of valid responses</b>
Pilot questionnaire	11	11
SurveyMonkey link (internet website)	175	136
Hard copy questionnaire	38	38
<b>Total</b>	<b>224</b>	<b>185</b>

#### **4.7.4 Qualitative Data Collection through Interviews**

According to Merriam (2009), qualitative research methods are the ideal methods to extract information based on knowledge and experience. Qualitative research derives meaning expressed through words, collected non-standardized data requiring classification and conducts analysis through conceptualization (Saunders *et al.*, 2012). Hence to achieve the research objective, interviews were conducted to study the benefits of BIM, the barriers to it, and the strategies to be adopted for its implementation in order to support the construction industry of Saudi Arabia. The participants used for this research had different subjective views, and qualitative data collection through the use of interviews allowed them to express their opinions in their own way and explain their own experience in relation to the use and influence of BIM in the Saudi Arabian construction industry. In turn, this allowed for the construction of valid explanations and conceptualizations from the details provided.

#### **4.7.4.1 The Interview Design**

By referring to the standard best practice guidelines as recommended by Bryman (2012), the starting point for the design of the interview questions was based on findings from the critical review of the literature with respect to the research aim and objectives. Thus, the semi-structured interview questions were carefully designed to elicit the interviewees' ideas and opinions on the topic of interest.

Primarily the interview questions are set out in the following themes:

- The first two questions related to the interviewees' organizations, speciality, area of operations, and their individual working experience.
- The subsequent two questions were based on communication between team members whilst working on construction projects.
- The next set of three questions were based on the interviewees' understanding of BIM, their awareness of its benefits, and their fears about adopting BIM within their organization and in the Saudi Arabian construction industry as a whole.
- Then some wide-ranging questions were set out to gauge the interviewees' opinions regarding the barriers to BIM adoption within Saudi construction organizations, the challenges facing its adoption and how these could be addressed.
- Next, a comprehensive set of questions were designed to assess the interviewees' attitudes regarding the strategies for BIM adoption in Saudi Arabia, and how these could be implemented, as well as opinions as to who were the main actors, so as to ensure the successful and strategic adoption of BIM in the Saudi Arabian construction industry.
- The interview questions then moved on to ascertaining the government's role in BIM adoption in Saudi Arabia and further asked if it was necessary to create new roles and responsibilities or departments for BIM implementation in Saudi Arabia.
- Furthermore, the importance of BIM education and training as a strategy for BIM adoption was explored using the interviews.
- Finally the interviewees were asked for their opinion concerning what would be the way forward for BIM adoption in Saudi Arabia.

The interviews were conducted in the Arabic language because it was preferred by the participants, so that they could express themselves easily and clearly and share their views on all the above information sourced from them. Initially, the above key issues were explored at

a deeper level using a series of general open-ended questions. These were then followed up by several sub-questions to source additional information, depending on the interviewees' response to each question. The method and procedures adopted for analysing the qualitative data collected is discussed in Section 4.8.2.

#### **4.7.4.2 The Sampling Process**

The participants who were selected for the semi-structured interviews had experience of working on both BIM-enabled and traditional construction projects. Sbaraini *et al.* (2011) assert that purposive sampling (a non-probability sampling technique, also known as initial sampling) is one of the vital characteristics of a qualitative study. In addition to this they also mention that the purposive sampling should be adopted in selecting those particular samples who are the best few persons to explain the basic concerns of the study. Groenewald (2004) adds that in a phenomenological approach to a qualitative study, the data should contain the perspective of the people who are directly involved with the particular agenda. Accordingly, the sampling of the interview participants for this research has taken this into consideration.

As the number of construction organizations that have implemented BIM throughout the Kingdom Saudi Arabia is unknown, the researcher attended a BIM workshop held in Riyadh Saudi Arabia on 27 December 2016, and spoke to some of the other attendees as well as the speakers at this workshop in order to gauge their knowledge and opinions of BIM. The researcher asked them if their respective organizations had implemented BIM or if they had enough knowledge of BIM to take part in the interviews for this research. The researcher also went on to ask the attendees about the types of projects they had worked on that implemented BIM and on what types of construction projects. Subsequently, the researcher attempted to invite these construction professionals to take part in an interview. However, while a large number of them responded, some did not respond at all.

Moreover, the interview participants were selected from the professionals who are directly involved with the application of BIM in construction projects. To acquire a deep understanding of the research topic, Saudi construction professionals who had a wide-range of work experience and were working on construction projects of different sizes and locations were invited for interview. All the participants were anonymised in this research due to ethical considerations. As suggested by Groenewald (2004), participants were selected who were directly involved in a project to a reasonable capacity. For the purpose of achieving a wider understanding, the interview participants included the people who were involved in

design, management, and implementation process of BIM in the projects they had worked on. Interviewees were from different disciplines such as architects, designers, MEP consultants or project managers, civil engineers, BIM managers, BIM coordinators, planners, and university lecturers. The lecturers were selected as samples in the survey because they were also involved in BIM application through their private professional practice, in which they engaged on a part-time basis. In total, eleven interviews were conducted between December 2016 and February 2017. These were considered to fulfil the adequacy of the sample for theoretical saturation.

#### **4.7.5 Concurrent Data Collection**

To ensure the data collection process made the best use of the availability of research participants, this research conducted data collection concurrently. Thus, conducting interviews and questionnaires survey concurrently helped in ensuring the responses were independent, thereby leading to more reliable results. Creswell and Clark (2007) report that the use of concurrent mixed methods of data collection helps to achieve a number of things: to validate one form of data by means of the other form; to transform the data for comparison; and to address different types of questions. Driscoll *et al.*, (2007) add that the advantages of concurrent data collection methods include: allowing participants to answer intuitively; and helping the research team to link the answers by relating the structured and unstructured responses. Throughout the process, the concurrent nature of the process helped to ensure that the qualitative responses were used to augment and explain complex or contradictory survey responses.

### **4.8 DATA ANALYSIS**

The categorization, examination, tabulation, testing or combination of both quantitative and qualitative results for addressing the original proposals of the investigation are referred as the procedure of data analysis (Yin, 2013). The analysis of the collected data was carried out in a reliable manner which was coherent with the collection procedures and kind of data collected. This section offers a brief description of procedures used in the analysis of the data collected for the research.

#### **4.8.1 Quantitative Data Analysis**

Saunders *et al.*, (2012), indicate that the main purpose of quantitative data is to derive meanings from numbers, resulting from numerical and standardized data and that the data

must be analysed through diagrams and statistics. Saunders *et al.*, (2012), also suggest that numerical data from surveys can be analysed using 'Descriptive' or 'Inferential' statistics. The descriptive statistics produces an expressive analysis of the questionnaire survey data collected; this could be conducted by different approaches such as mean, average and mode. Descriptive statistics are used to describe the central tendency of the data as well as describe the dispersion of the data from the central tendency (Denscombe, 2007). While the inferential statistics are conducted through probability and correlational statistics. Inferential statistics allow the data to be tested for strength and significance of relationships between variables (Saunders *et al.*, 2012).

Furthermore, the data from the electronic questionnaire and the paper copies of the questionnaire had to be combined together to analyse the data collected, in order to generate the findings accurately. Thus, the data from each paper copy was individually placed into the electronic questionnaire survey by the researcher using the internet link. A number of incomplete questionnaire survey responses were received in which only the demographic questions were answered, thus these had to be rejected as unusable for the study, due to the lack of information available from them.

As a result, after the data had been collected, it was analysed by the use of descriptive and inferential statistics. The questionnaire data was then interpreted by the use of SPSS (Statistical Package for the Social Sciences) to confirm that the results are appropriate for the data analytic methods selected for the research. The methods used in the analysis of data included descriptive statistics, inferential statistics, cross-tabulation and the Kendall correlation test.

Spearman's Rank correlation coefficient and Pearson correlation coefficient were not used because Spearman's Rank correlation coefficient describes monotonic relationships while the Pearson correlation coefficient describes linear relationships. Whereas Kendall rank correlation is statistically more comprehensive for testing non-linear relationships than both the Spearman's Rank correlation coefficient and the Pearson correlation coefficient as it is designed to capture the association between two ordinal variables.

**Kendall rank correlation coefficient** is a non-parametric test to determine the degree of correlation (the strength and direction of association) that exists between two quantitative variables of ranked data. Kendall correlation is a statistic test which uses ordinal data to give the association between two variables. It is much less sensitive to error and discrepancies in



data than Spearman's correlation coefficient (Argyrous, 2011). The Kendall correlation coefficient returns a value of -1 to 1, where:

- 0 is no relationship
- 0 to  $\pm 0.2$  is a very weak relationship
- $\pm 0.2$  to  $\pm 0.4$  is a weak relationship
- $\pm 0.4$  to  $\pm 0.6$  is a moderate relationship
- $\pm 0.6$  to  $\pm 0.8$  is a strong relationship
- $\pm 0.8$  to  $\pm 1.0$  is a very strong relationship
- $\pm 1$  is a perfect relationship

In order to foresee or predict the behaviour of variables, correlation is necessary. A correlation coefficient usually shows the value of a relationship between variables. Correlation normally takes a value in between -1 and +1 where the positive correlation interprets that both variables will be increasing or decreasing and the negative correlation interprets that if one variable increases then the other variable will decrease and vice versa (Argyrous, 2011). In the case of hypothesis testing, correlation analysis has been used to check the associations in the hypotheses. When there is no association between the variables in the study then the null hypothesis will be taken into consideration and when there is association between the variables in the study then the chosen hypotheses will be taken into consideration. Moreover, the test of significance for Kendall's correlation coefficient is used to validate the hypothesis defining the monotonic correlation between the sample populations of the study (Argyrous, 2011).

The significance is based on the Kendall's correlation coefficient determined for the sample. Correlation coefficients significant at the 0.05 level are indicated as a single asterisk whereas correlation coefficients significant at the 0.01 level are also indicated as a double asterisk (Hinton *et al.*, 2014). The correlation is considered significant if the significance level (p-value) is very small (less than 0.05) and the variables are linearly correlated with each other. On the other hand, if the significance level (p-value) is very large (such as 0.50) then correlation is considered not significant and there will be no linear correlation between the variables (Wilcox, 2001).

Kendall's tau-b ( $\tau_b$ ) correlation coefficient (Kendall's tau-b, for short) is a nonparametric measure of the strength and direction of association that exists between two variables

measured on at least an ordinal scale (Hinton *et al.*, 2014). It is considered a nonparametric alternative to the Pearson's product-moment correlation when the data has failed one or more of the assumptions of this test. It is also considered an alternative to the nonparametric Spearman rank-order correlation coefficient. If one of the variables is considered as an independent variable and the other as a dependent variable, then a Somers' D test will be considered instead (Hinton *et al.*, 2014).

The Kendall rank correlation coefficient evaluates the degree of similarity between two sets of ranks given to the same set of objects. This coefficient depends upon the number of inversions of pairs of objects which would be needed to transform one rank order into the other. In order to do so, each rank order is represented by the set of all pairs of objects (e.g., [a, b] and [b, a] are the two pairs representing the objects a and b), and a value of  $\pm 1$  or 0 is assigned to this pair when its order corresponds or does not correspond to the way these two objects were ordered (Wilcox, 2001). This coding schema provides a set of binary values which are then used to compute a Kendall correlation coefficient. The Kendall correlation between the two variables will be high when the observations between two variables have similar rank and low when the observations between two variables have different rank (Argyrous, 2011). This is expected to help shed more light on BIM awareness, adoption and implementation as well as barriers in the KSA construction industry, which can ultimately lead to efforts to help establish a base for industry-wide adoption.

#### **4.8.2 Qualitative Data Analysis**

The researcher used explanation building (Yin, 2013) as a method of qualitative data analysis. It enabled the qualitative raw data to be thoroughly scrutinised and several explanations were used to discover the associations between the objects of research. This resulted in analytical conclusions that answered the original "how" and "why" research questions.

The qualitative data gathered through the interviews were analysed with the help of the thematic content analysis method which helped establish the meaning of the data through encoding and decoding of the data, searching and retrieving of the data and the formation of themes which indicated the intercalations within the data gathered (Boyatzis, 1998). This method is considered to be a suitable and malleable way of collecting and communicating ideas and themes that arise during an interview (Aronson, 1994). Braun and Clarke (2006)

further argue that this approach provides the researcher with rich and detailed meaning out of the responses of the interview.

The response from the interviews were recorded and later transcribed in a word-perfect manner to prepare data for the analysis. On average each interview lasted 45 minutes and the transcriptions were read several times to have a good understanding of the general ideas and also identify the decisive ideas across the interviews which were related to the aims and objectives of the study (Creswell, 2006; Flick, 2009). The interviews were designed based on best practice guidelines as suggested by Bryman (2008). The semi-structured interviews could be broken into five sections. Section A requested information on the respondents and their company profile, section B requested information based on level of awareness and understanding on BIM, section C focused on fears and barriers to the implementation of BIM in the industry, section D focused on strategies to be adopted in the implementation of BIM and section E requested information on tools to be used to ensure the implementation of BIM.

According to Boyatzis (1998), different codes are to be allocated to words, phrases and segments within the transcript of the analysis of the qualitative data which are relevant to the research question, aim and objectives of the research study. Furthermore, as set out by Braun and Clarke (2006), the coded words and segments were studied, reorganized and collated under relevant themes. The codes were then categorised into potential themes. For example, data extracts such as "expensive", "costly", "increase the project cost", "involve lots of money" and "huge financial implication" were coded as "cost of implementation" and categorised under the theme "barriers to adoption of BIM in Saudi Arabian construction industry"

The different themes identified from the interview were: the awareness level of BIM, fears of adopting BIM in the construction industry, barriers to adoption of BIM, strategies for BIM adoption, tools for BIM adoption and the outcome BIM will have on the organization when put into practice.

The research adopted a guide proposed by Braun and Clarke (2006) and Creswell (2009) to analyse the 11 interviews as discussed below:

### **1. Familiarity with the data**

In order to fully analyse the collected data, it becomes necessary to have a good understanding of the interviewees' responses. Therefore, the researcher went through the data

corpus over and over, while identifying the emerging issues that relate to the research questions and objectives. Relevant issues and possible relationships between these issues were also identified and noted for coding purposes.

## **2. Transcribing the data**

According to Bird (2005), the transcription of interviews is very helpful in analysing them. Similarly, Braun and Clarke (2006) suggested that transcription is very vital in achieving an effective thematic analysis. Therefore, the interviews were initially transcribed word to word and then those conducted in Arabic were translated into English. The transcription and translation processes helped the researcher to become more familiar with the data. Though non-verbal expressions could not be captured in the transcripts, the transcription process also gave the researcher a deeper understanding of the content.

## **3. Identification of meaningful issues and patterns**

The next stage of the analysis was to identify the meaningful issues and patterns arising across the interviews. At this stage, the transcripts were read over and over to identify the relevant issues and patterns arising across the interviews as well as finding possible links between the issues identified. This also involved marking some segments, phrases and words that relate to the research question or problem. These were then collected together using codes.

## **4. Generating the initial codes**

At this stage of the data analysis, codes were used to organize the above segments into meaningful categories (Miles and Huberman 1994; Tuckett 2005). This was done by using labels for the extracted words and phrases above which relate to the research question. Therefore, codes were used to bring meaning out of the data corpus and establish links and patterns across the whole interview transcripts.

## **5. Collating the extracts**

The next step after assigning codes to the various extracts was to group the codes under various themes. However, this was done in a way that reflects the interview as a whole based on clear understanding and interpretations of the researcher, keeping aside personal views of the researcher. The coded data extracts were then used to define the themes and issues developing from the analysis. The extracts were also used to define titles for the different themes.

## **6. Reorganization and renaming of themes**

The categorised extracts with similar codes were further re-organized and re-examined with respect to the whole transcript to ensure that it was in line with the context where it was originally mentioned in the interview (Anderson 2007). In some cases, the categories were merged or broken down where it is found more appropriate. Hence, some themes were renamed to a more suitable title.

## **7. Interpretation and Discussion**

The final themes and categorised extracts were then used to compile and discuss findings from the thematic analysis. The discussion was further enriched with quotations from the interview transcripts to give the reader a better understanding of the findings. In addition, findings from the interview were further compared and discussed in respect to findings from the literature review.

## **4.9 VALIDITY AND RELIABILITY**

Validity and reliability are terms that can at times be interchanged with one another. They help in assessing the research quality. The term reliability is defined by the Oxford Living Dictionaries (2017) as “consistently good in quality or performance; able to be trusted” (pp 711), and it defines validity as “[the] quality of being logically and officially binding or acceptable” (pp 981). Peräkylä (2011) states that the validity of any research relates to the explanation of observations and that it does not depend on the interference produced by the researcher which may be supported by data. In relation to reliability in social science research, Drost (2011) suggests that the essence of reliability is to ensure that the findings of the research relate to the reality.

### **4.9.1 Reliability**

This correlates with the matter of measures. According to Bryman and Bell (2015), there are factors that apply to measuring reliability which can be:

- Stability reliability: the ability to measure a concept as valid as with the passage of time. It is always measured over a period of definitive time and whether it holds true after all the time or not can be seen.
- Internal reliability: key indicators that make up the scale of measure should be consistent during a study. If the relevant indicators of a concept measure are not consistent or scored opposite; then an internal unreliability can be recorded.

The measures taken to ensure that the findings of this research are reliable are discussed in section 5.5 and the validation chapter (see Section 8.2).

#### **4.9.2 Validity**

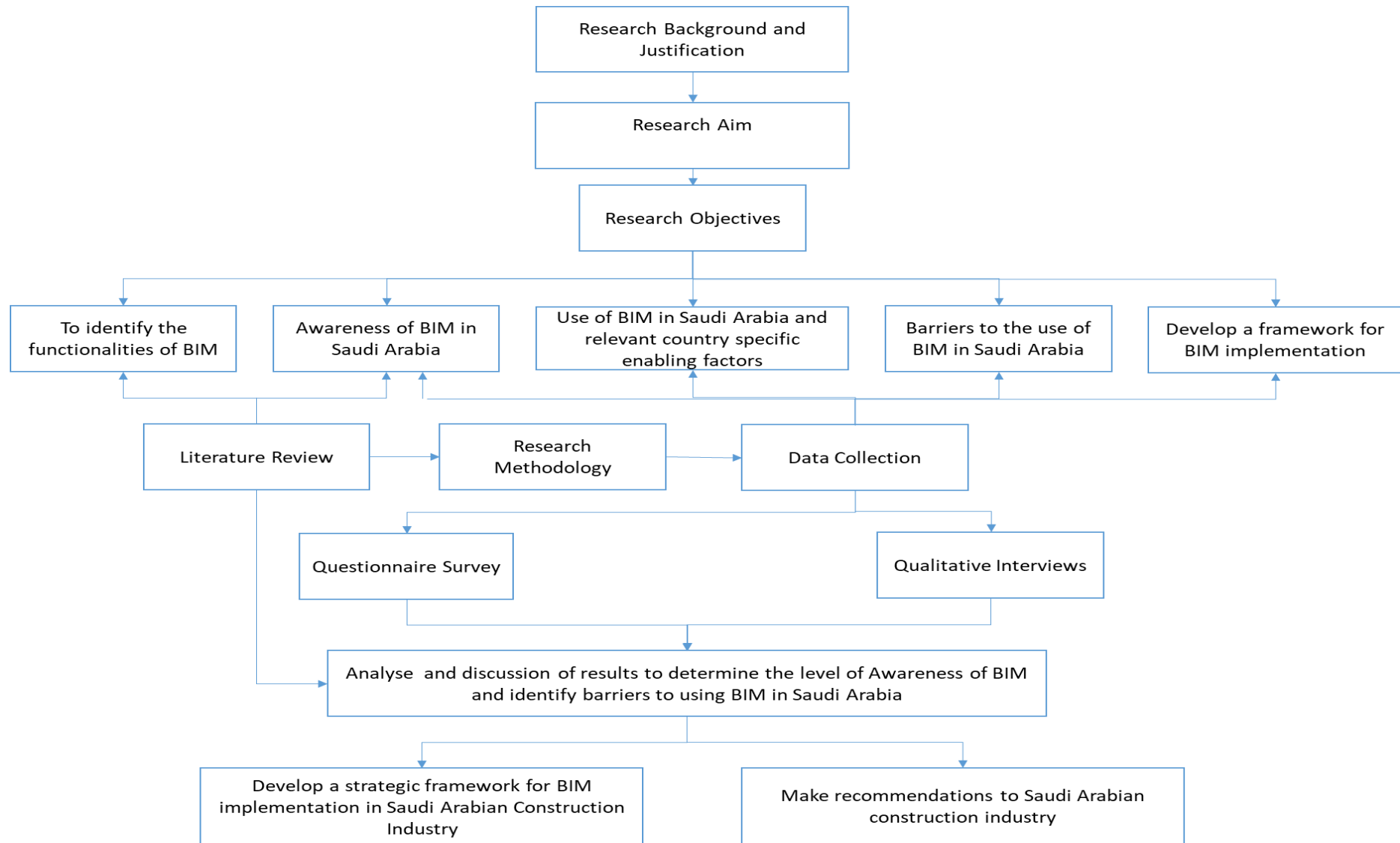
The validation of the research is the process of the measurement of the concepts in focus, and it is known as validity. It is explained as authority, legitimacy and rationality for the acceptance of the notion. Bryman and Bell (2015) classify validity into five diverse groups:

- Face validity: This is the process of relating the subject face to the context. It is conducted to make sure the measurement reflect the content of the concept in question.
- Concurrent validity: When a researcher is dealing with criterions that are related to subjective perspectives, there is a need to take the research analysis further.
- Predictive validity: Modern methods are not significant in comparison to the future criteria.
- Construct validity: The researcher postulates hypotheses from the theories pertinent to the notion. For instance, a situation of cause and effect.
- Convergent validity: The researcher may wish to measure certain notions by the comparisons of results using various methods related to research.

The measures taken to validate the findings of this research are discussed in the validation chapter (see Section 8.2).

#### **4.10 DIAGRAM OF RESEARCH DESIGN**

The diagram of research design for this research is driven and addresses the description and explanation of key conditions that influence the degree of the successful outcome of the BIM adoption process in Saudi Arabia. The diagram shown in Figure 4.3 indicates how the design of this research can help achieve the aim of the study.



**Figure 4.3: Overview of the Research Design**

#### **4.11 SUMMARY OF CHAPTER FOUR**

This chapter has discussed the relevant literature in relation to the research methodology. The philosophies of research, as well as strategies and the methods of data collection were deliberated in detail with the intention of comprehending the applicable strategies and philosophies for undertaking the study on BIM in addition to why such a useful tool is not widely used in the Kingdom of Saudi Arabia, and if it is not fully utilized then what the barriers are to this. Through the discussion, the researcher has debated that this specific study on BIM in Saudi Arabia takes the philosophical stance of pragmatism and adopted the mixed method approach to address the research problem. This has led to the selection of a questionnaire and interview (mixed methods) as being the particularly appropriate research strategies with a brief examination of the strengths as well as weaknesses of these methods. The next two chapters discuss the analysis and findings from the quantitative and qualitative studies.



# **CHAPTER FIVE**

## **QUANTITATIVE DATA ANALYSIS**

### **5.1 INTRODUCTION TO CHAPTER FIVE**

As stated in the methodology chapter (Chapter 4), this research collected both quantitative and qualitative data concurrently with the aim of capturing and understanding the current state of BIM implementation in Saudi Arabia. This chapter presents the analysis and discussion of results from the quantitative data captured. The essence of this chapter is to provide a picture of the current usage of BIM, the reasons for adopting BIM and the anticipated barriers to the adoption of BIM in Saudi Arabia and to compare this with the extant literature.

The chapter is divided into three main sections. The first part presents information on the demographic profile of the respondents to the research. Part two presents the descriptive statistics on the data collected in relation to BIM adoption and use. The final part analyses and discusses the relationships between the variables of this research through correlational analysis. The quantitative data gathered from this research was analysed using descriptive and inferential analytical tools. Kendall's correlation was used to test the relationship between the different variables studied in this research.

### **5.2 DEMOGRAPHIC PROFILES OF THE ORGANIZATIONS**

This section provides demographic information on the participants for this research including the response rate, background of participants, their age group and their job descriptions. The information provided in this section provides a basis for analysing the views of participants on BIM adoption, implementation, barriers and strategies.

#### **5.2.1 Background of the Participants**

To ensure the data collected is representative of the industry, it was necessary to collect data from all the stakeholders in the construction industry. Table 5.1 below shows the categorization of the organizations and individuals in the organizations that took part in the survey. Respondents from five different organizations completed and returned questionnaires.

**Table 5.1: Demographic Profile of Organizations**

<b>Organization</b>	<b>Frequency</b>	<b>Percentage</b>
Contractor	61	27.2
Consultant	84	37.5
Client	32	14.3
Client's representative	38	17.0
University	9	4.0
<b>Total</b>	<b>224</b>	<b>100.0</b>

As can be seen from Table 5.1, responses from the consultant organization are the highest in terms of frequency (84). This represents 37.5% of the entire research respondents. The University category has the lowest proportion of respondents, only 4% of the total. This distribution presents an interesting group to obtain information from regarding BIM awareness and adoption. Traditionally, consultants are expected to introduce an idea, in this case BIM, to the clients who can then make it a requirement for their projects (Rogers *et al.*, 2015; Eastman *et al.*, 2011).

Of respondents who undertake projects exclusively for organizations in either public or private sector works, the data shows that respondents whose organizations undertake projects in public sector works are more than those who undertake private sector works projects. Specifically, 30.8% of the respondents undertake projects for public sector works, while 19.2% do so for private sector works. The remaining 50.0% of the sample size undertake projects for both public and private sector works. Again, this suggests that the views captured for this research are representative of the industry, as people from both sides (public and private sector) undertook the research. The relevance of both public and private sector construction professionals in relation to BIM adoption is discussed by Bin Zakaria *et al.* (2013), who suggest that the private sector plays a key role in advising the public sector and even government in developing a national BIM agenda.

### **5.2.2 Age Group and Experiences of the Respondents**

The age and experience of participants were deemed important in this research. As BIM is an emerging process and technology, there is a general perception that young professionals who naturally have an attraction for technology would easily be encouraged to adopt BIM. The group of 26–35 year old respondents contains the highest number of research participants, representing 42.9% of the sample size. This is followed by the age group 36–45, representing

29% of the entire sample size. These two age groups together (out of the 5 different age groups) represent over 70% of the entire sample size. This shows that the majority of the respondents to this survey are within the range of middle aged professionals.

Experience in the industry is very important, as this, combined with the age of respondents, has the ability to influence the practices known to respondents as well as how much they are likely to know about the industry. In terms of experience, almost 60% of the entire sample size have several years (between 6 and 25 years) of experience working in the construction sector of Saudi Arabia. This shows that the research participants have significant years of experience and suggests they would have considerable knowledge of the construction sector of Saudi Arabia.

### 5.2.3 Job Description of the Participants

This section provides information on the roles played by the participants to this survey. This helps to shed more light on how the awareness and use of BIM may differ based on the different roles played by the respondents in their respective organizations. Table 5.2 below, shows the position or job description of the research respondents.

**Table 5.2: Job Descriptions of The Participants**

<b>Current position, or job description</b>	<b>Frequency</b>	<b>Percent</b>
Director of the organization	40	17.8
Project Manager	57	25.4
Construction Manager	10	4.5
Architect	31	13.8
Planning Team Member	18	8.0
Civil Engineer	31	13.8
Quantity Surveyor	1	0.4
Safety Manager	1	0.4
Lecturer /Academic	9	4
Engineer in construction projects	26	11.6
<b>Total</b>	<b>224</b>	<b>100.0</b>

Table 5.2 above, which shows the position or job description of the research respondents, indicates that Project Managers participated in the study, representing about 25% of the sample size and the highest number of respondents. Directors also participated in the study,

representing about 18% and making this role the one with the second highest number of respondents in the study. The senior positions and the role descriptions of the research respondents in their respective organizations and their number of years of work experience in the construction sector of Saudi Arabia indicate that they are key players in this industry of Saudi Arabia. Therefore, the respondents' opinions are important and reliable for providing answers to the research questions on BIM in the construction sector of Saudi Arabia. The relevance of job descriptions in relation to BIM can be identified in terms of the extent of BIM knowledge required and the extent to which BIM is used on projects. As reported in Arayici *et al.*, (2011), there is increasing pressure on different professionals in the industry from clients to adopt and implement BIM on projects. This research therefore seeks to identify whether similar results can be found from the construction industry of Saudi Arabia.

### **5.3 USE OF BIM IN SAUDI ARABIA**

This section presents the analysis of the data regarding the use of BIM in the Saudi Arabian construction industry. The section presents information on the familiarity of the respondents with BIM, the use of BIM and the reasons for its use. The results are then compared to the literature to determine how the familiarity of the respondents and their use of BIM relates to familiarity and use of BIM elsewhere.

#### **5.3.1 Familiarity with BIM**

In identifying the level of BIM knowledge among the respondents, it was important to investigate their familiarity with BIM. Whereby familiarity equates to the knowledge, acquaintance and awareness of BIM. Out of the 224 respondents, 17% stated they were not aware of BIM. Over 80% of the entire group of respondents indicated different levels of BIM awareness and extent of BIM usage in terms of how competent they were in using BIM. The results suggest that the level of awareness and familiarity within the Saudi Arabian construction industry is quite low.

This is shown in Table 5.3 where, as indicated, there are four levels or categories of BIM awareness among the different organizations surveyed. The purpose of the cross-tabulation is to help provide information on the levels of BIM awareness across and within the different organizations.

**Table 5.3: Cross-Tabulation Between Familiarity with BIM  
and Description of Organization**

		Type of respondent and/or their organization					Total
		Contractor	Consultant	Client	Client’s representative	University	
How familiar are you with ‘Building Information Modeling’ (BIM)?	Not aware	12	12	8	6	1	39
		19.7%	14.3%	25.0%	15.8%	11.1%	17.4%
	Somewhat familiar	12	17	8	13	2	52
		19.7%	20.2%	25.0%	34.2%	22.2%	23.2%
	Fairly familiar	28	29	10	13	1	81
		45.9%	34.5%	31.3%	34.2%	11.1%	36.2%
	Well versed in it	5	18	5	5	0	33
		8.2%	21.4%	15.6%	13.2%	0.0%	14.7%
	An expert user	4	8	1	1	5	19
		6.6%	9.5%	3.1%	2.6%	55.6%	8.5%
Total		61	84	32	38	9	224
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 5.3 above shows that most of the respondents (36.2%) are fairly familiar with the use of BIM. Of this number, the majority work with consultant organizations (29), and so represent 34.5% of the entire number of consultants in this research. The contractor organizations (28) represent 45.9% of the entire number of contractors in this research. In relation to their specific role, respondents that are fairly familiar with BIM usage are mostly Project Managers (30.9%), Civil Engineers (17.3%), and Directors (16%). The option “An expert user” has the least respondents (8.5%). Out of this number, 8 work in a consultant organization, 5 are in academia, 4 in a contractor organization and 1 each works for a client and client’s representative organization respectively. In terms of their special role, 7 of the “expert users” of BIM are Architects, 4 are Project Managers, 3 are Engineers, 2 each are Directors and Lecturers, and 1 is a Civil Engineer. The small number of expert users of BIM is perhaps an indication of its novelty in KSA. This result is similar to research by Bin Zakaria *et al.*, (2013) who suggest that the lack of skilled BIM personnel is one of the main

challenges to the adoption of BIM in the Malaysian construction industry. Barison and Santos (2011) report that for proper BIM implementation, current job roles require specific BIM competencies.

This result also indicates that awareness of BIM is not very high in the Saudi Arabian construction industry. Of all the people sampled, about 40% either have very little familiarity with BIM or are not aware at all of its existence. This indicates that measures to help introduce BIM and help in its adoption will be very important. The measures will be further discussed as part of the proposed framework to be generated as part of this research. Familiarity with BIM, however, does not suggest that participants have used BIM for their projects in the Saudi Arabian construction industry. Little awareness here suggests that training personnel on the advantages of BIM and the processes involved in its adoption and implementation will be essential if the Saudi Arabian construction industry is to implement BIM.

### **5.3.2 Familiarity with the Use of BIM Training**

As a further step, this research collected data on the experience of the participants with BIM. This section provides information on the outcome of this result. Table 5.4 presents the findings for BIM training within the organizations surveyed. It shows variations in the number of BIM in-house training sessions attended by respondents in each of the organizations. The findings show that 4 of the respondents in a university organization (Academia) stated they did not attend any form of BIM training within their organization. From the respondents in a consultant organization, 29 stated that they had never attended any in-house training sessions.

**Table 5.4: Cross-Tabulation Between Training and Description of Organization**

			Type of respondent and/or their organization					Total
			Contractor	Consultant	Client	Client's representative	University	
How many BIM training/coaching sessions have you attended within your organization? (Include in-house training, short courses, workshops and seminars in your response)	None	Count	26	29	8	19	4	86
			53.1%	40.3%	34.8%	59.4%	44.4%	46.5%
	1	Count	10	18	7	4	1	40
			20.4%	25.0%	30.4%	12.5%	11.1%	21.6%
	2	Count	9	9	5	4	2	29
			18.4%	12.5%	21.7%	12.5%	22.2%	15.7%
	3	Count	0	3	2	2	0	7
			0.0%	4.2%	8.7%	6.3%	0.0%	3.8%
	4	Count	2	0	1	1	0	4
			4.1%	0.0%	4.3%	3.1%	0.0%	2.2%
	More than 4	Count	2	13	0	2	2	19
			4.1%	18.1%	0.0%	6.3%	22.2%	10.3%
Total		Count	49	72	23	32	9	185
			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The number of respondents who had never attended any training was 86, representing about 46.5% of out of the 185 who responded to the question. This figure is the highest compared to the other five options. The next largest number and percentage is for the option of respondents who attended one training sessions within their organization. 40 respondents, representing 21.6% attended training sessions within their organization, while 15.7% attended two within their organizations. In addition, only 10.3% of respondents attended more than 4 training sessions within their organizations, while 3.8% and 2.2% of respondents attended 3 and 4 in-house training sessions respectively.

This result indicates that the number of BIM training sessions within the different organizations is not very high. This result also indicates that even though a large number of respondents have some awareness of BIM (as shown in Table 5.3), this awareness or the level of knowledge is likely to be shallow. Awareness of BIM can be said to be very low as such training and even in house-coaching is very low. The essence of training organizational employees in BIM is to ensure that a knowledge of BIM is increased, which can ultimately lead to an increase in its adoption across the organizations.

Succar *et al.*, (2013) suggest that individual BIM competencies are the building blocks of organizational BIM capability. From the results, it can then be concluded that organizational capability in relation to BIM within the Saudi Arabian construction industry is very low, considering the low awareness of the individual workers and the small amount of training from their organizations. Lee and Hollar (2013) report that adequate BIM training is essential to advancing the construction industry into the BIM era.

### **5.3.3 Frequency of Use**

Table 5.5 shows different levels in the use of BIM. For instance, 26.4% of respondents had never used BIM in their organizations. Contractors constituted the highest number (13) while clients' representatives had the highest percentage (40%) out of the entire number of clients' representatives who answered that they had never used BIM. The number of respondents who had used BIM frequently was 52 out of 144 respondents who were aware of BIM processes, software or tools. This represents about 36.1%, and respondents in the consultant organization used BIM more frequently than other organizations. They constituted 25 out of the 52 respondents in this category. Overall, the results showed a good usage of BIM in the various organizations. 106 out of the 144 respondents had used BIM to one degree or another. This figure represents about 73.6 % of the research participants who answered the question



on the frequency of BIM usage. Bin Zakaria *et al.* (2013) report that the low adoption and usage of BIM is due to the low level of awareness of it. The low usage or experience with BIM in the Saudi Arabian construction industry can therefore be associated with the low awareness. As shown in section 5.3.1, there is low familiarity with BIM within the industry and this can be related to the low level of usage.

To check for the level of awareness or usage across different organizations, a cross-tabulation was conducted. The output for the cross-tabulation can be observed in Table 5.5.

**Table 5.5: Cross-Tabulation Between Use of BIM and Description of Organization**

			Type of respondent and/or their organisation					Total
			Contractor	Consultant	Client	Client’s representative	University	
Please indicate the frequency with which your company uses BIM software/ tools/applications.	Never used	Count	13	11	5	8	1	38
			31.7%	18.0%	33.3%	40.0%	14.3%	26.4%
	Occasion-ally used	Count	10	8	1	4	2	25
			24.4%	13.1%	6.7%	20.0%	28.6%	17.4%
	Frequently used	Count	12	25	6	7	2	52
			29.3%	41.0%	40.0%	35.0%	28.6%	36.1%
	Always used	Count	6	17	3	1	2	29
			14.6%	27.9%	20.0%	5.0%	28.6%	20.1%
Total		Count	41	61	15	20	7	144
			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Furthermore, the result show differences in the frequency of BIM usage for respondents whose organizations undertake projects for either public or private sector works. The results show in terms of percentage that respondents who have never used BIM have undertaken slightly more projects for private sector works (36.8%) out of the entire number of private sector respondents who answered this question compared to those whose organizations have undertaken public sector works (35.1%). Overall, the percentage of respondents who have used BIM at one level of frequency or another is slightly higher for projects in public sector works (64.8%) out of the entire number of public sector respondents who answered this question than for projects for the private sector works (61.3%). However, the results indicate that the frequency of BIM usage in the “Always used” option is higher for respondents whose organizations undertake private sector works projects (10.5%) out of the entire private sector who answered this question, than projects for public sector works (8.1%).

The differences in the usage levels between the public and private sector suggests that there is room for BIM education in terms of awareness and benefits. The public sector has a major role to play in this regard. For countries like the UK, where BIM adoption and awareness is on the increase, there have been efforts by the public sector and government in particular on the enactment of legislation to promote the adoption and implementation of BIM.

Comparing the use of BIM to the level of training or coaching received for it, the research results suggest that some of the respondents may have used BIM without any training or coaching. This is likely to have affected the performance or their BIM capabilities. The lack of skills and minimal awareness of BIM, although it is believed to be a game changer in the industry, can be linked to the assertion by Al-Jibouri (2009) that even though there have been some improvements in the construction industry of Saudi Arabia, ineffective planning and failures during construction remain significant challenges.

#### **5.3.4 Reasons for the Use of BIM in Saudi Arabia**

Considering the level of BIM usage, awareness and training received by the respondents, this research sought to gather views from the respondents on the reasons behind their BIM usage or adoption. Information from this section is expected to shed light on the drivers for BIM adoption and usage in Saudi Arabia. Table 5.6 below presents the findings on the reasons for the use of BIM in the organizations surveyed.

**Table 5.6: Findings on the Reasons for the Use of BIM in Organizations**

Reasons for using BIM within your organization: (You may select more than one)	
Answer Options	Response Count
It creates views and schedules automatically	71
It reflects changes instantly in all drawings and schedules	82
Less paperwork, and multiple files are avoided	71
It is compatible with data exchange standards for inter-operability	34
It is required by our clients	24
It is required by other project team members	29

From Table 5.6 it can be observed that participants were presented with 6 different reasons why they had implemented BIM in their organizations. They were allowed to choose more than one reason. The findings indicate that the reasons: “it is required by our clients” and “it is required by other project team members” received the lowest scores: 24 and 34 respectively.

This result is not surprising, considering the result on the level of awareness of BIM within the client group. Assaf and Al-Hejji (2006) suggest that the client has a major role to play regarding the characteristic problems in the Saudi Arabian construction industry. The low level of awareness within this group can be seen to contribute to this problem, as the potential to reduce some of the problems is being missed by the industry. Overall, this finding indicates that the use of BIM might not be a key requirement for awarding contracts and executing construction projects in the Kingdom of Saudi Arabia.

However, the findings suggest that few organizations have made the use of BIM mandatory for project execution. Such organizations can be said to be going in the right direction and making the industry better, and so in the future there need to be systems in place that can support and increase the awareness of the industry in this regard. As reported by Sidawi *et al.*, (2013), some organizations in the Saudi construction industry are now assessing how to avail themselves of the benefits of technology in their construction processes. This suggests that as with BIM, the use and adoption of such technology will be linked to the companies’ ability to see the benefits it presents.

The majority of the scores for the reasons stated above are from contractor and consultant organizations. The reasons with high scores, such as “It reflects changes instantly in all drawings and schedules”, show that the main reasons why participants implement BIM are not entirely based on industry requirements or government regulations, but are a result of the perceived benefits of BIM in improving productivity in the workplace. As gathered from these results, the contractors and consultant organizations who use BIM do so because of the benefits they can identify. As discussed in Arayici, Egbu and Coates (2012), the benefits of BIM can lead to a significant change in the success rate of the industry by helping to solve most of the problems it faces. Arayici, Egbu and Coates speak of benefits such as cost reduction, efficiency, quality, and increase of productivity, lead times and avoidance of duplication, using effective communication with the stakeholders in construction projects (2012). These benefits are very likely to help the Saudi construction industry, considering its current problems, and making the parties in the industry aware of the potential of BIM to deliver such benefits therefore becomes very important and can lead to increased adoption.

### **5.3.5 The Processes Improved by Using BIM Instead of 2D/3D CAD**

This section presents the findings on the processes improved by the use of BIM instead of 2D/3D CAD. Participants were allowed to select more than one option from a list of 7 options and to state any other reasons not included in the options as can be seen in Table 5.7 below. The option “production of drawings and schedules” received the highest score (129). This shows that the majority of the participants viewed this option as the most improved process when using BIM in place of 2D/3D CAD.

**Table 5.7: The Processes Improved by Using BIM Instead of 2D/3D CAD**

The processes improved by using BIM instead of 2D/3D CAD	
Answer Options	Response Count
Production of drawings and schedules	129
Visualization	94
Programming	65
Costing	99
Energy Analysis	50
Greater collaboration with consultants and other project team members	86

I do not know	14
Other reasons (please specify)	12

Costing is the second most improved process, and received a score of 99, while visualization with a score of 94 was the third most improved process when BIM was implemented. This suggests that the respondents have some ideas about the importance or the benefits of adopting BIM. It is therefore important that the industry is made aware of the different levels of BIM maturity and the benefits that come with each maturity level (See Bew and Underwood, 2010).

The benefits of adopting BIM, as discussed in Chapter 3, go beyond producing drawings and costings, to encompass the construction process itself. Results from Al-rashed *et al.* (2014), as well Sidawi and Al-Sudairi (2014), suggest that BIM can improve conventional construction project management methods and techniques and so it would be very important to bring this knowledge to the attention of the participants so they can see BIM improving processes beyond just designing and costing.

The option “I do not know” had one of the lowest scores (14). The participants in this category were not sure about which process were improved when using BIM compared to 2D/3D CAD. It could also imply that the participants were not certain whether there were any improvements at all when BIM was used: in other words, that there might not have been any significant difference between using BIM and 2D/3D CAD. The majority of the participants who chose this option were involved in construction projects for both the public and private sectors (8), while 5 were involved in construction projects for the public sector and 1 for the private sector.

From the results provided, it can be identified that the drivers for the adoption of BIM in the Saudi Arabian construction industry can be attributed mainly to some clients who have begun to demand the use of BIM from the parties to their projects.

Another driver for BIM adoption, according to this research, is the realization of the benefits of BIM. From the results, contractors and consultants are the main parties that acknowledge this as a reason for using BIM. Research by authors such as Kymmell (2008), Eastman *et al.*, (2008), Smith and Tardif (2009), Azar (2011), Eastman *et al.*, (2011), and Bynum *et al.*, (2013) suggest that realising the importance of BIM, many people within the industry will opt

for its benefits, which, according to the respondents, come in the form of improving the processes within the construction industry.

## **5.4 CORRELATIONS BETWEEN AWARENESS, BENEFITS, BARRIERS AND STRATEGIES**

To further explore the awareness and use of BIM within the KSA construction industry, this research conducted correlational tests between the variables of the study. This section sets out in detail the analysis carried out using Kendall's correlation coefficient within SPSS Statistics.

This is expected to help shed more light on BIM awareness, benefits, adoption and implementation as well as on the barriers in the KSA construction industry, and so can ultimately lead to efforts to help lay the base for industry-wide adoption.

### **5.4.1 Correlation between Group of Respondents and Awareness, Benefits, Barriers and Strategies**

Further to the questionnaire analysis, under this section the relationship between Age Group and the Awareness, Benefits, Barriers and Strategies for BIM Adoption in Saudi Arabia is discussed. The relationship is derived from the Kendall correlation coefficient in SPSS for a sample size of 185. As presented in Gledson and Gledson (2016), a younger generation of professionals is expected to be more technology-aware and likely to have greater awareness regarding BIM and its benefits, when compared to an older generation. The relationships between the Age Group of construction professionals and the different components under the broad theme "Awareness, Benefits, Barriers and Strategies for BIM Adoption in Saudi Arabia" are shown in Table 5.8 below. This is to help identify and differentiate between the views of younger professionals, who are generally regarded to be 'digital natives', and older professionals, who are likely to have started their careers when there was little or less use of computers.

A Kendall's correlation was run in order to determine the relationship between the age of the participants and their perception about the growing demand of BIM usage in Saudi Arabia, amongst 185 respondents. From the correlation it was found that there was a very weak positive correlation about the perception of the demand for BIM usage in Saudi Arabia with different age groups of participants as being that the demand for BIM in Saudi Arabia is not too high, which is statistically significant (Kendall's correlation coefficient,  $T_b = 0.1750$ ,

significance,  $p = 0.0054$ ). This very weak correlation suggests that even though there are some differences regarding the perception of the respondents by age, this is not very strong. These results were rather unexpected as the younger generation were expected to have different views (and better in this case) regarding the need for BIM in the Saudi Arabian construction industry. This can be said to contribute to the low level of awareness and adoption of BIM in the construction industry. The younger generation of professionals are expected to have a better understanding of the more current issues in the industry and of the use of BIM as a means to help overcome some of the challenges of the industry.

The correlation between each age group of the respondents and the implication of BIM in evaluating the full project life cycle shows a very weak, but positive and linear correlation which is found significant as  $T_b = 0.1394$ ,  $p = 0.03$ . Again, a positive relationship was found regarding the participants' perceptions about the visualization of a real time model project using BIM with respect to the age group of the respondents ( $T_b = 0.1464$ ,  $p = 0.0235$ ). Again, some of the respondents felt that BIM software would be too expensive to implement ( $T_b = 0.126$ ,  $p = 0.043$ ) and that BIM software was difficult to learn ( $T_b = 0.133$ ,  $p = 0.032$ ). This perception was expected, as the older generation are generally seen as not being 'digital natives' and as such would find the learning and adoption of new technology difficult (Morton, 2012). The subject of digital natives has been discussed in different areas of research as the difference between the younger generation and the older generation, whether in construction or any other sector. It was therefore not surprising to discover that the older generation of professionals used in this research found BIM technology adoption and implementation quite difficult. This result also suggested the need for more education on the use of BIM within the industry.

The view gathered that BIM will be too costly to adopt can be said to have an impact on the level of adoption. Porwal and Hewage (2013), report that cost is seen as one of the main barriers to the adoption of BIM within the industry, and similar results are presented by Stanley and Thurnell (2014). High initial costs can therefore be identified as one of the main barriers to the adoption of BIM.

Furthermore, regarding the participants' thoughts about the availability of competent staff in Saudi Arabia in operating BIM, it was found that there was a very weak but positive correlation which is statistically significant at ( $T_b = 0.151$ ,  $p = 0.018$ ), with different age groups of participants stating that there are few staff in Saudi Arabia who can operate BIM,



as can be seen in Table 5.8. Thus, even though this correlation was positive but very weak, there was a general consensus among the participants that there are not enough staff within the industry who have the skills set regarding BIM usage. Comparing this result to the results with the level of awareness and use of BIM, it confirms that the level of BIM awareness within the industry is low.

The results presented from this correlation suggest that the age of respondents is a factor influencing their views on BIM and its adoption or implementation. Gledson and Gledson (2016) and Enegbuma *et al.*, (2015) all suggest that the different ages of professionals produce different perceptions towards the adoption and implementation of BIM, and this can be attributed to different generations affecting technological capabilities differently. In research by Underwood *et al.*, (2015) into UK construction education and BIM, it was also identified that a relationship exists between age and BIM-related issues.

**Table 5.8: Relationship Between Age Group and Awareness, Benefits, Barriers and Strategies for BIM Adoption in Saudi Arabia**

QUESTION 1: Age Group			
Questions		Correlation	Significance
Awareness & Benefits	q0021: There is a growing awareness of BIM usage in Saudi Arabia.	0.1092	0.0798
	q0022: There is a growing demand for BIM usage in Saudi Arabia.	0.1750**	0.0054
	q0023: The use of BIM shortens the overall project timescale.	0.0573	0.3766
	q0024: The use of BIM reduces the overall project cost	0.1133	0.0767
	q0025: The use of BIM minimizes construction conflicts.	0.0265	0.6821
	q0026: The use of BIM makes information more accessible to project team members.	0.0053	0.935
	q0027: The use of BIM can improve the design of a building.	0.0206	0.7527
	q0028: The use of BIM makes communication more straightforward.	0.0293	0.6534
	q0029: The use of BIM makes project sequencing/scheduling easier.	0.0884	0.1753
	q0030: Full project Life Cycle evaluations can be conducted using BIM.	0.1394*	0.03
	q0031: A real time model of the project can be visualized with the use of BIM.	0.1464*	0.0235

<b>Barriers</b>	q0034: BIM is not required by clients.	0.118	0.059
	q0035: There is no (legal) practice guide to support the use of BIM in Saudi Arabia.	0.099	0.123
	q0036: BIM is not required by team members such as architects and engineers.	0.090	0.148
	q0037: BIM software is too expensive.	0.126*	0.043
	q0038: BIM is difficult to learn.	0.133*	0.032
	q0039: The non-availability of a parametric library hinders the uptake of BIM.	0.055	0.387
	q0040: It takes a longer time to develop a BIM model.	0.106	0.091
	q0041: There is a lack of competent staff in Saudi Arabia to operate the BIM software.	0.151*	0.018
	q0042: BIM does not add much value to our organization.	-0.002	0.971
<b>Strategies</b>	q0044: The importance of BIM should be further promoted with construction clients in KSA.	0.105	0.105
	q0045: The use of BIM should be regulated.	0.062	0.335
	q0046: The training of construction staff on using BIM is needed.	0.071	0.277
	q0047: BIM should be introduced in the curricula of Saudi Arabian universities.	0.102	0.117
	q0048: More efforts are needed to make BIM interoperable.	0.040	0.538
	q0049: Adopting BIM will give Saudi construction organizations added value.	0.089	0.174
	q0050: The changes needed by Saudi organizations in order to adopt BIM are too problematic.	-0.084	0.184
	q0051: The Saudi Government specifically and actively provides support to encourage the adoption of BIM by construction organizations.	-0.047	0.459
	q0052: The Saudi Government specifically provides financial subsidies to promote the adoption of BIM by construction organizations.	-0.010	0.869
	q0053: A law is needed to compel practitioners to use BIM.	0.035	0.578

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

It is therefore not surprising that the results produced in this table suggest that the age of respondents correlates with awareness, benefits and barriers of BIM. For younger professionals with higher technological capabilities, there is a general perception that BIM can easily be learnt, whereas older generation respondents are of the view that BIM learning will be difficult. This again relates to Gledson and Gledson (2016), who report that variance

in technological capabilities is a result of different age generations. It should however be pointed out that the respondents' views on the need for BIM adoption in Saudi Arabia is not differentiated by age.

#### **5.4.2 Correlation between Educational Level and Awareness, Benefits, Barriers and Strategies**

To determine the extent to which the educational level of the respondents influenced their views on the awareness, benefits, barriers and strategies to BIM implementation in Saudi Arabia, a Kendall correlation was conducted. The relationship between the highest formal education qualification of the participants and the awareness, benefits, barriers and strategies of BIM in Saudi Arabia is shown in Table 5.9 below.

The findings showed a weak and very weak correlation between construction professionals with different formal education qualifications (question 2 from the questionnaire survey) and BIM awareness in Saudi Arabia and other benefits of BIM. In the case of the barriers to adopting BIM in Saudi Arabia, there was a weak and very weak correlation with respect to the components from the questionnaire, which implies that the participants believed that BIM adds value to their construction organization. In the case of the strategies for BIM adoption and implementation in Saudi Arabia, participants of different formal levels of educational qualification felt that there was a substantial need to promote BIM with construction clients, hence many efforts will be needed to make BIM inter-operable, organizations need to change their project modelling with BIM, and the Saudi government should promote and encourage BIM adoption.

**Table 5.9: Relationship Between Highest Formal Education Qualification and Barriers, Strategies, Awareness and Benefits of BIM in Saudi Arabia**

<b>Question 2: Highest Formal Education Qualification</b>		
<b>Questions Regarding Barriers, Strategies, Awareness and Benefits</b>	<b>Correlation</b>	<b>Significance</b>
Q21: There is a growing awareness of BIM usage in Saudi Arabia.	0.1611*	0.012
Q25: The use of BIM minimizes construction conflicts.	0.1841**	0.0056
Q27: The use of BIM can improve the design of a building.	0.1529*	0.023
Q28: The use of BIM makes communication more straightforward.	0.1904**	0.0045

Q29: The use of BIM makes project sequencing/scheduling easier.	0.2161**	0.0013
Q30: Full project Life Cycle evaluations can be conducted using BIM.	0.1686*	0.0107
Q31: A real time model of the project can be visualized with the use of BIM	0.2504**	0.0002
Q35: There is no (legal) practice guide to support the use of BIM in Saudi Arabia.	0.186**	0.005
Q39: The non-availability of a parametric library hinders the uptake of BIM.	0.181**	0.005
Q40: It takes a longer time to develop a BIM model.	0.215**	0.001
Q41: There is a lack of competent staff in Saudi Arabia to operate the BIM software.	0.153*	0.019
Q42: BIM does not add much value to our organization.	-0.139*	0.03
Q44: The importance of BIM should be further promoted with construction clients in KSA.	0.168*	0.011
Q45: The use of BIM should be regulated.	0.154*	0.021
Q46: The training of construction staff on using BIM is needed.	0.143*	0.033
Q48: More efforts are needed to make BIM inter-operable.	0.188**	0.005
Q50: The changes needed by Saudi organizations in order to adopt BIM are too problematic.	0.148*	0.022
Q51: The Saudi Government specifically and actively provides support to encourage the adoption of BIM by construction organizations.	0.131*	0.044

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

As shown by the correlation, higher educational levels generally correlate with better awareness of BIM and its benefits for the KSA construction industry. This result also suggests that the better or more informed respondents (professionals) are about BIM, the better their view on its benefits and the need to implement it in the construction industry. Research by different authors, for instance Sacks and Pikas (2013), Wu and Issa (2013), and Lee and Hollar (2013) have all discussed the importance of education in influencing the perceptions of construction professionals on BIM adoption and implementation. Education of professionals on BIM helps to improve their understanding and even assists in identifying benefits which can help improve the perceptions on the need for adoption. From the correlations it can also be identified that higher educational levels also correlate positively with the knowledge of professionals on the requirements for having BIM adopted and implemented in the industry.

As shown in the table, there is a general view that there is a lack of competent staff for implementing BIM in the KSA construction industry and hence the need for improved education with an emphasis on BIM. Lee and Hollar (2013) report that BIM should be included as part of the curriculum for construction professionals.

#### **5.4.3 Correlation between Years of Work Experience and Awareness, Benefits, Barriers and Strategies**

The relationship between years of work experience pertaining to construction projects and the awareness, benefits, barriers and strategies of BIM in Saudi Arabia is discussed here. Table 5.10 below shows the correlation and significance test value to find out the relationship between the years of work experience of construction professionals and the different components above as set out in question 3 of the questionnaire.

Construction professionals in Saudi Arabia with varying years of experience of working in the construction industry think that there is growing demand for BIM ( $T_b = 0.1346$ ,  $p = 0.0267$ ), BIM can be fully used for evaluating a full project life cycle ( $T_b = 0.1363$ ,  $p = 0.0279$ ), BIM can be used in visualizing a real time model of a construction project ( $T_b = 0.1594$ ,  $p = 0.0106$ ), and BIM software is too expensive ( $T_b = 0.131$ ,  $p = 0.029$ ) and hard to learn ( $T_b = 0.129$ ,  $p = 0.032$ ). On the other hand, they feel that the importance of BIM should be further promoted with construction clients in KSA ( $T_b = 0.146$ ,  $p = 0.019$ ) and the use of BIM should be regulated ( $T_b = 0.135$ ,  $p = 0.03$ ). As well as BIM should be introduced into the curricula of Saudi Arabian universities ( $T_b = 0.127$ ,  $p = 0.043$ ), and more efforts are needed to make BIM inter-operable. ( $T_b = 0.141$ ,  $p = 0.026$ ). The results here indicate a practical understanding of the requirements for BIM.

**Table 5.10: Relationship Between Years of Work Experience Pertaining to Construction Projects and Barriers, Strategies, Awareness and Benefits of BIM in Saudi Arabia**

<b>Question 3: Years of Work Experience Pertaining to Construction Projects</b>		
<b>Questions Regarding Barriers, Strategies, Awareness and Benefits</b>	<b>Correlation</b>	<b>Significance</b>
Q22: There is a growing demand for BIM usage in Saudi Arabia.	0.1346*	0.0267
Q30: Full project Life Cycle evaluations can be conducted using BIM	0.1363*	0.0279
Q31: A real time model of the project can be visualized with the use of BIM.	0.1594*	0.0106
Q34: BIM is not required by clients.	0.124*	0.04

Q35: There is no (legal) practice guide to support the use of BIM in Saudi Arabia.	0.14*	0.024
Q37: BIM software are too expensive.	0.131*	0.029
Q38: BIM is difficult to learn.	0.129*	0.032
Q44: The importance of BIM should be further promoted with construction clients in KSA.	0.146*	0.019
Q45: The use of BIM should be regulated.	0.135*	0.03
Q47: BIM should be introduced into the curricula of Saudi Arabian universities.	0.127*	0.043
Q48: More efforts are needed to make BIM inter-operable.	0.141*	0.026

\*. Correlation is significant at the 0.05 level (2-tailed).

As can be seen from the results, the general perceptions of the respondents suggest that there is a relationship between experience in Saudi Arabian construction industry and the variables tested. Where people have more experience, they are more likely to understand the need for and possible benefits of BIM in project implementation. Although the general level of understanding regarding BIM is low, the more experienced respondents showed a better understanding of the key requirements needed to ensure that BIM adoption and implementation would lead to the required results.

#### **5.4.4 Correlation between the Description of Organization and Awareness, Benefits, Barriers and Strategies**

As shown in Table 5.11 below, the only significant correlation was the one found between the type of organization and the questions set out in part 3, 4 and 5 of the questionnaire regarding the awareness, benefits, barriers and strategies. Although this correlation is very weak, it suggests that BIM is generally regarded by the parties as having an influence on communication within the industry. The other variables not presenting significant correlations are likely to be as a result of the low level of awareness and experience of BIM in the construction industry.

**Table 5.11: Relationship Between Description of Organization and Barriers, Strategies, Awareness and Benefits of BIM Adoption in Saudi Arabia**

<b>Question 5: Description of Organization</b>		
<b>Questions Regarding Barriers, Strategies, Awareness and Benefits</b>	<b>Correlation</b>	<b>Significance</b>
Q28: The use of BIM makes communication more straightforward.	0.159*	0.014

\*. Correlation is significant at the 0.05 level (2-tailed).

Poor communication has been cited by Assaf and Al-Hejji, (2006) as one of the key issues in the Saudi construction industry. The realization that BIM can make communication between the parties more straightforward can be seen as a very good basis to support the adoption and implementation of BIM in the Saudi construction industry.

#### **5.4.5 Correlation between the Current Job Position and Job Description and Awareness, Benefits, Barriers and Strategies**

The Kendall correlation with respect to the relationship between the current job position and job description of the participants of the study and the awareness, benefits, barriers and strategies of BIM adoption in Saudi Arabia is discussed in Table 5.12 below. The table shows that there is a negative very weak correlation between the job positions and the view that “there is no (legal) practice guide to support the use of BIM in Saudi Arabia” ( $T_b = -0.173$ ,  $p = 0.004$ ). This shows that a good number of the respondents do not believe that there is no legal guide to support the implementation of BIM in Saudi Arabia.

**Table 5.12: Relationship Between Current Job Position or Job Description and Barriers, Strategies, Awareness and Benefits of BIM Adoption in Saudi Arabia**

<b>Question 6: Your Current Position or Job Description</b>		
<b>Questions Regarding Barriers, Strategies, Awareness and Benefits</b>	<b>Correlation</b>	<b>Significance</b>
Q35: There is no (legal) practice guide to support the use of BIM in Saudi Arabia.	-0.173*	0.004
Q36: BIM is not required by team members such as architects and engineers.	-0.136*	0.022
Q47: BIM should be introduced into the curricula of Saudi Arabian universities.	-.0162*	0.009

\*. Correlation is significant at the 0.05 level (2-tailed).

Similarly, there is a negative very weak correlation ( $T_b = -0.136$ ,  $p = 0.022$ ) between the job positions and the opinion that “BIM is not required by team members such as architects and engineers”. Therefore, the respondents do not believe that BIM is not required by professionals like architects and engineers. In addition, it can be deduced from the table that there is a very weak correlation between current job and the view that “BIM should be introduced into the curricula of Saudi Arabian universities” ( $T_b = -0.162$ ). These results were rather surprising as the current low levels of BIM awareness and adoption mean there is a demand for better training to be provided by incorporating BIM into current curriculum. The findings from the qualitative study and the literature (Al-Hammad, 1995; Middle East, 2011;

Al-Mohannadi *et al.*, 2013) show that there is a strong need for BIM to be incorporated into the curriculum of colleges and universities which offer courses in Architecture and the Built Environment.

#### **5.4.6 Correlation between Type of Construction Organization and Awareness, Benefits, Barriers and Strategies**

In considering the benefits of BIM, this section of the analysis sought to determine whether the type of construction projects that the participants undertake had any significant relation with their views on BIM awareness, benefits, barriers and strategies. The relationship between the types of construction projects of different organizations in Saudi Arabia and awareness, benefits, barriers and strategies of BIM in Saudi Arabia are discussed in Table 5.13 below.

A Kendall's correlation was run in order to determine the relationship between the participants from different organizations that used to undertake different construction projects and their perception about the growing demand for BIM usage in Saudi Arabia, amongst 185 respondents. From the correlation it was found that there is a very weak but positive correlation regarding the perception of the demand for BIM usage in Saudi Arabia, that the demand of BIM in Saudi Arabia is not too high, but is statistically significant (Kendall's correlation coefficient,  $T_b = 0.1460$ , significance,  $p = 0.025$ ). On the other hand, a negative correlation is found between the participants of different construction project-based organizations and their responses to 'BIM does not add much value to our organization', ( $T_b = -0.148$ ,  $p = 0.022$ ).

**Table 5.13: Relationships Between the Types of Construction Projects Undertaken and Barriers, Awareness and Benefits of BIM in Saudi Arabia**

<b>Question 8: Types of Construction Projects Your Organization Undertakes</b>		
<b>Questions Regarding Barriers, Awareness and Benefits</b>	<b>Correlation</b>	<b>Significance</b>
Q22: There is a growing demand for BIM usage in Saudi Arabia.	0.1460*	0.025
Q42: BIM does not add much value to our organization.	-0.148*	0.022

\*. Correlation is significant at the 0.05 level (2-tailed).

From this result, it is identified that experience on different project types affect the views of participants on the demand for BIM. Parties who have worked on complex projects with



some experience of BIM would usually be expected to identify the demand for BIM on such projects. Again the results gave a negative correlation on whether or not BIM adds value to organizations, thus indicating that the more complex the projects people have worked on, the more likely they are to be able to see the value-adding capabilities of BIM. From this it can therefore be concluded that the benefits of BIM can be realised with large and complex projects where many different parties will have various roles to play.

#### **5.4.7 Correlation between Cost of Projects and Awareness, Benefits, Barriers and Strategies**

From Table 5.14 below, the correlation analysis about the relationships between the highest project costs of organizations involved in the construction industry and awareness, benefits, barriers and strategies of BIM in the construction industry of Saudi Arabia it was found that there is a weak correlation between growing awareness ( $T_b = 0.2670$ ,  $p = 0$ ) and growing demand ( $T_b = 0.2490$ ,  $p = 0$ ) for BIM usage in Saudi Arabia, which is statistically significant. On the other hand, there is negative weak correlation between the highest project cost in a construction organization and 'BIM doesn't add much value to the construction organization in Saudi Arabia ( $T_b = -0.238$ ,  $p = 0$ ). Again, in the case of a construction organization involved in high cost projects, there is a very weak correlation with the cost-effectiveness and conflict minimization applications of BIM in a construction project. There is a very weak and positive correlation between the need for BIM promotion to construction clients in Saudi Arabia ( $T_b = 0.134$ ,  $p = 0.041$ ), while a very weak correlation is found in the case of the need for regulation and law for practitioners who are using BIM.

**Table 5.14: Relationship Between the Highest Cost of Projects and Barriers, Awareness and Benefits of BIM in the Construction Industry of Saudi Arabia**

<b>Question 10: The Highest Cost of Projects Your Organization Has Been Involved In</b>		
<b>Questions Regarding Barriers, Awareness and Benefits of BIM</b>	<b>Correlation</b>	<b>Significance</b>
Q21: There is a growing awareness of BIM usage in Saudi Arabia.	0.2670**	0
Q22: There is a growing demand for BIM usage in Saudi Arabia.	0.2490**	0
Q24: The use of BIM reduces the overall project cost.	0.1340*	0.041
Q25: The use of BIM minimizes construction conflicts.	0.1980**	0.003
Q42: BIM does not add much value to our organization.	-0.238**	0
Q44: The importance of BIM should be further promoted with construction clients in KSA.	0.134*	0.043

Q45: The use of BIM should be regulated.	0.195**	0.003
Q53: A law is needed to compel practitioners to use BIM.	0.178**	0.005

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

The results identified in this section suggest that the higher the cost of the projects in which participants have been involved, the better their understanding or perception of BIM. This result is expected as larger projects are generally seen as a good avenue for BIM implementation and adoption due to the number of parties involved. There was a negative correlation between increasing project costs and the view that BIM does not add value to the organization and this is an indication that people who have been on large projects are more likely to see or know the benefits of BIM on their projects and within their organizations. The results are comparable with those of Bin Zakaria *et al.*, (2013). For projects with higher cost outlays, the consensus is that the use of BIM should be regulated ( $T_b = 0.195$ ,  $p = 0.003$ ). BIM regulations should consist of a clear interpretation of all the roles and responsibilities of all the participants and stakeholders in the construction project at any given time. This calls for a document known as a common standards, guideline or code of practice for the uniform delivery of information and data in addition to a common working methodology for BIM usage.

#### **5.4.8 Correlation between Familiarity with BIM and Awareness, Benefits, Barriers and Strategies**

The relationship between familiarity with BIM and the awareness, benefits, barriers and strategies of BIM in Saudi Arabia are discussed in Table 5.15 below. Depending on the level of familiarity with BIM, it is expected that participants may have some knowledge about the benefits of BIM and its implementation.

A very weak correlation was found between familiarity with BIM and growing awareness of BIM in Saudi Arabia ( $T_b = 0.1310$ ,  $p = 0.036$ ), BIM will reduce project completion timescale ( $T_b = 0.1470$ ,  $p = 0.024$ ), cost-effectiveness of BIM, conflict reduction during project with the help of BIM usage, BIM makes information more straightforward and easily accessible to the project members, and BIM can be used to visualize the real time model of the project.

On the other hand, there was weak correlation between familiarity with BIM and the participants' view that BIM does not add much value to their organization ( $T_b = -0.231$ ,  $p =$

0). Again, some of the participants felt that BIM should be regulated (a very weak correlation), more efforts are needed to make BIM operable, and adoption of BIM will be valued in Saudi construction organizations. A very weak correlation was found between familiarity with BIM and ‘Saudi Government specifically provides financial subsidy to promote the adoption of BIM by construction organizations’, which implies that the Saudi Government needs to become more focused and provide financial support to promote BIM (statistically significant,  $T_b = 0.131$ ,  $p = 0.038$ ). The correlation results for familiarity with BIM and the efforts of the government in relation to BIM suggest that even though participants may be familiar with BIM, they are not likely to know about government interventions throughout the process. This is also likely to be because participants are not aware of the role of government intervention in other countries and how this has helped with BIM adoption and implementation. This result makes the need for government efforts relating to BIM adoption and implementation very important.

**Table 5.15: Relationship Between Familiarity With 'Building Information Modelling' (BIM) and Barriers, Strategies, Awareness and Benefits of BIM in Saudi Arabia**

<b>Question 11: Familiarity With 'Building Information Modelling' (BIM)</b>		
<b>Questions Regarding Barriers, Strategies, Awareness and Benefits</b>	<b>Correlation</b>	<b>Significance</b>
Q21: There is a growing awareness of BIM usage in Saudi Arabia.	0.1310*	0.036
Q23: The using of BIM will shorten the overall project timescale.	0.1470*	0.024
Q24: The use of BIM reduces the overall project cost.	0.1910**	0.003
Q25: The use of BIM minimizes construction conflicts.	0.1850**	0.005
Q26: The use of BIM makes information more accessible to project team members.	0.1410*	0.031
Q28: The use of BIM makes communication more straightforward.	0.1550*	0.018
Q29: The use of BIM makes project sequencing/ scheduling easier.	0.1810**	0.006
Q30: Full project Life Cycle evaluations can be conducted using BIM.	0.2540**	0
Q31: A real time model of the project can be visualized with the use of BIM	0.2050**	0.002
Q35: There is no (legal) practice guide to support the use of BIM in Saudi Arabia.	0.194**	0.003

Q42: BIM does not add much value to our organization.	-0.231**	0
Q45: The use of BIM should be regulated.	0.160*	0.014
Q47: BIM should be introduced into the curricula of Saudi Arabian universities.	0.164*	0.012
Q48: More efforts are needed to make BIM inter-operable.	0.162*	0.014
Q49: Adopting BIM will give Saudi construction organizations an added value.	0.133*	0.044
Q52: The Saudi Government specifically provides financial subsidy to promote the adoption of BIM by construction organizations.	0.131*	0.038
Q53: A law is needed to compel practitioners to use BIM.	0.218**	0.001

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).

From this correlation analysis, it is quite clear that there is a need for people within the industry to know more about BIM and its value-adding capabilities. In line with the results, it can be concluded that the more familiar people are with BIM, the better their understanding of its importance, the need for it and measures that can support BIM implementation. Parties familiar with BIM also suggest that there is no legal guide that can help parties in adopting and implementing BIM. This calls for the need to have a guide, whether from government or other recognised institutions within the Saudi Arabian construction industry, which can help the industry in its journey towards adopting BIM.

#### **5.4.9 Correlation between Extent of BIM Training and Coaching and Awareness, Benefits, Barriers and Strategies**

This correlation sought to test how the extent of BIM training and coaching received by participants related to their views on the awareness, benefits, barriers and strategies of BIM, as shown in Table 5.16 below.

Participants who had attended training sessions about BIM within their organization were asked to respond with their thoughts on the increase of BIM awareness in Saudi Arabia. A weak but positive correlation was found ( $T_b = 0.2910$ ,  $p = 0$ ). Similarly, a very weak correlation was found regarding the growing demand of BIM but the relation was significant ( $T_b = 0.1930$ ,  $p = 0.002$ ). Again, there was a very weak correlation between the participants who had attended training sessions about BIM within their organization and the cost effectiveness, straight communication benefits, and evaluation of full project life cycle using BIM. A few respondents found that it took a longer time to develop and implement the BIM

model and a few of them felt that more effort needed to be made in order for BIM to become inter-operable.

**Table 5.16: Relationships Between number of BIM Training/Coaching Sessions Attended and Barriers, Strategies, Awareness and Benefits of BIM in Saudi Arabia**

<b>Question 12: How Many BIM Training/Coaching Sessions Were Attended Within Work Organization</b>		
<b>Questions Regarding Barriers, Strategies, Awareness and Benefits</b>	<b>Correlation</b>	<b>Significance</b>
Q21: There is a growing awareness of BIM usage in Saudi Arabia.	0.2910**	0
Q22: There is a growing demand for BIM usage in Saudi Arabia.	0.1930**	0.002
Q24: The use of BIM reduces the overall project cost.	0.1650**	0.01
Q28: The use of BIM makes communication more straightforward.	0.1310*	0.043
Q30: Full project Life Cycle evaluations can be conducted using BIM.	0.1900**	0.003
Q40: It takes a longer time to develop a BIM model.	0.147*	0.019
Q42: BIM does not add much value to our organization.	-0.150*	0.015
Q48: More efforts are needed to make BIM inter-operable.	0.137*	0.036
Q53: A law is needed to compel practitioners to use BIM.	0.151*	0.015

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

From the results of this correlation, a common outcome is the need for improved education on BIM and the benefits it possesses. Even though the correlations found above were weak and very weak, there was a general realization among participants who had received some BIM training in the Saudi Arabian construction industry that BIM comes with benefits for the organizations and their projects. The very weak correlations between parties who had attended some training sessions and their views on BIM reduces overall cost of projects can be attributed to the fact that the benefits of BIM can fully be realised when well implemented (Stanley and Thurnell, 2014). This can also be attributed to the low level of knowledge or expertise which the participants have in relation to BIM. Concerns such as the time it takes to develop BIM models might be drawbacks to people's views on the need for implementation unless the full benefits can be realised. As identified from the number of training sessions

attended, it can be seen that many of the respondents had attended few sessions and might not be in a position to fully understand or realise the full capabilities of BIM implementation. Perceptions of BIM have been reported by Enegbuma *et al.*, (2015) to influence the adoption of BIM. There is a need, therefore, to ensure that the parties in the construction industry have the correct knowledge of BIM, its barriers and benefits so the right perceptions may be formed. This will in turn positively affect the attitude of parties towards the adoption of BIM in the Saudi construction industry.

#### **5.4.10 Correlation between the Number of Projects Developed and Handled with the Help of BIM and Awareness, Benefits, Barriers and Strategies**

The essence of this correlation was to test whether respondents who had had experience with BIM on different projects were likely to have different views on BIM implementation and adoption compared to respondents with little or no such experience.

The relationship between the number of projects developed and handled by the respondents in this study with the help of BIM and the awareness, benefits, barriers and strategies of BIM in Saudi Arabia are discussed in Table 5.17 below.

From the Kendall's correlation run between the numbers of project handled by participants with the help of BIM and their perception about the growing awareness and demand of BIM in Saudi Arabia, a weak correlation was found between these variables ( $T_b = 0.2850$ ,  $p = 0$  and  $T_b = 0.2760$ ,  $p = 0$  respectively). There was a very weak correlation between the perception of participants about the importance of BIM in reducing overall project cost and that of the participants who had handled some BIM projects ( $T_b = 0.1300$ ,  $p = 0.041$ ). On the other hand, a negative correlation was found between the participants who had handled some BIM projects and their responses about 'BIM does not add much value to our organization', ( $T_b = -0.269$ ,  $p = 0$ ). These results suggest that people who have used BIM on projects have perhaps seen the value added to their projects by adopting BIM. As presented in the literature review, BIM has many benefits which lead to increased value in adopting BIM on projects (See Chapter 3). The benefits of adopting BIM, as discussed earlier, is related to the maturity level of BIM adopted and this is linked to the personnel involved in the adoption of BIM (Bew and Underwood, 2010).

Again, a very weak correlation was found between the participants' perception about BIM regulation and the need for a law to compel BIM users with respect to the experiences of participants in handling BIM based projects. This very weak correlation can be attributed to

the little experience by most participants with BIM implementation. Results from Powal and Hewage (2013) and Eadie *et al.*, (2013) suggest that government regulations play a key role in the adoption and implementation of BIM.

**Table 5.17: Relationships Between number of Projects Developed Using BIM and Barriers, Strategies, Awareness and Benefits of BIM in Saudi Arabia**

<b>Question 14: How Many Projects Have Been Developed Using BIM Within Your Organization</b>		
<b>Questions Regarding Barriers, Strategies, Awareness and Benefits</b>	<b>Correlation</b>	<b>Significance</b>
Q21: There is a growing awareness of BIM usage in Saudi Arabia.	0.2850**	0
Q22: There is a growing demand for BIM usage in Saudi Arabia.	0.2760**	0
Q24: The use of BIM reduces the overall project cost.	0.1300*	0.041
Q30: Full project Life Cycle evaluations can be conducted using BIM.	0.1480*	0.02
Q39: The non-availability of a parametric library hinders the uptake of BIM.	0.137*	0.029
Q42: BIM does not add much value to our organization.	-0.269**	0
Q45: The use of BIM should be regulated.	0.142*	0.027
Q53: A law is needed to compel practitioners to use BIM.	0.125*	0.045

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

From the analysis conducted in this section, all the variables show a positive relation with projects that have been developed using BIM with the exception of ‘BIM does not add value to the organization’. This is an indication that the more people use BIM on projects, the more they come to understand its use and importance, and the benefits it provides for the companies and their projects. The realization provides a strong support for the need for increased awareness and efforts to ensure BIM is implemented in the Saudi Arabian construction industry. This need brings with it the importance of education on BIM for the stakeholders in the construction industry.

The negative correlation found between the number of projects completed with BIM and the responses to ‘BIM does not add much value to the company’ is also an indication that people who have used BIM on projects can identify the impacts BIM has on the processes of the organization. As reported in Stanley and Thurnell (2014), in New Zealand the level of

experience with BIM corresponds with the knowledge of professionals concerning the benefits and barriers to the implementation of BIM. These results serve as a contribution to the need to ensure parties are educated to increase their awareness of BIM and the benefits it offers to the construction industry.

## **5.5 RELIABILITY OF RESEARCH FINDINGS**

The quality of research is found in the reliability of the research findings. As stated by Bryman and Bell (2007), reliability of research depends on ensuring consistency in terms of the measurement of the key concepts. This was achieved in this research by ensuring a consistent instrument for collecting data was designed. In analysing and presenting the data in section, every care was taken to ensure the research led to reliable results. As discussed in Section 4.9.1, the questionnaire is clearly understood by the respondents and free of any ambiguity. The piloting ensured that the questions are well understood and correctly interpreted. A stable reliability was achieved in such a way that the data collection period did not affect the validity of the questionnaire in any way.

## **5.6 SUMMARY OF CHAPTER FIVE**

This chapter has analysed and discussed the results of the quantitative data collected for this research. From the analysis of the data, it is evident that BIM awareness in the Saudi Arabian construction industry is not very high, even though there is a growing awareness of the benefits of BIM implementation in the industry. From this chapter, it has also been identified that there is a section of professionals who have had some experience with BIM implementation at different levels (although the level of experience is quite low), with many respondents agreeing that they have little knowledge and experience of BIM. The results also suggest that people with higher levels of education and more experience see the need for BIM in the Saudi Arabian construction industry and identify the benefits that are likely to be derived from proper implementation. From the factors needed for implementation of BIM, education and government support were identified as required for ensuring the benefits of BIM are achieved. In terms of reasons for implementing BIM, the results indicate that the perceived benefits of BIM implementation are the main drivers for its implementation.

The next chapter presents the results on the qualitative data collected through the use of interviews, done concurrently with the quantitative data. Information in the next chapter is expected to help shed more light on the issues presented in this chapter.



# CHAPTER SIX

## QUALITATIVE DATA ANALYSIS AND DISCUSSIONS

### 6.1 INTRODUCTION TO CHAPTER SIX

This chapter concentrates on the analysis of the qualitative data obtained through the interviews. The third objective of the research is to empirically investigate the extent and nature of the use of BIM and associated barriers in the Saudi Arabian construction industry (refer to section 1.7). The qualitative research was conducted to shed more light on the results from the quantitative research. In doing this, questions similar to that of the quantitative research were posed to interviewees, who were given the chance to explain the reasons for the answers they provided. Issues such as barriers to BIM implementation and the current level of understanding as presented in the quantitative research were key in the qualitative research phase and linked to objectives (iii), (iv) and (v) of this research. In order to address these objectives, the chapter presents an analysis of the data obtained through the qualitative study. The findings will then be used to develop a strategy for adopting BIM in Saudi Arabia.

Beyond the demographic information, questions posed in the interview were carefully designed to mirror that of the questionnaire survey. A summary of the links between the survey questions and the interview questions and the questionnaire survey is shown in the table 6.1 below.

**Table 6. 1 Comparison Between Qualitative and Quantitative Data Collection**

<b>Areas in Quantitative data collection</b>	<b>Link to Qualitative data collection</b>
Familiarity with BIM	Education and training on BIM (section 6.9)
Familiarity with use of BIM	Understanding of BIM in relation to the organisation (section 6.5)
Frequency of use of BIM	Sharing for project information (section 6.4) Fears of adopting BIM in the construction industry (section 6.6)
Reasons for the use of BIM	Strategies for BIM adoption and fears for

	BIM adoption (section 6.8 and 6.6)
Processes improved by BIM	Understanding of BIM in relation to organisation

## 6.2 THE DATA COLLECTION

In addition to the quantitative study, a qualitative study was concurrently undertaken to explore the level of awareness and understanding of BIM in the Saudi Arabian construction industry, as well as the barriers to its implementation and the strategies for its adoption. As discussed in Chapter Four, interviews were used in conducting the qualitative study. According to Schostak (2006), an interview can provide insights into the experiences, beliefs, values, knowledge, interests, and concerns of the other, as well as being a means of assessing their reasoning and actions. Therefore, to address the research objectives, interviews were considered to be an appropriate method for data collection.

Semi-structured interviews were conducted to obtain the primary data for this research study. The interviews were carried out with eleven Saudi construction professionals from both the public and private sectors. The selection criteria for the interview participants was on the basis of professional position and years of experience working in the Saudi construction industry, as well as awareness of BIM, as they had experience of working on many projects with the use of BIM.

For the purpose of this research, the semi-structured interview was the form chosen in order to conduct a qualitative study. Since the research involved developing strategies for BIM adoption in Saudi construction organizations, this required an input in the form of approaches and descriptions from the participating construction professionals. As a result, flexibility was needed in the interviews in terms of following up questions. Hence semi structured-interviews were selected, as they provide much needed flexibility while maintaining the overall structure of the interview themes.

## 6.3 PROFILE OF THE INTERVIEWEES

The interviews were conducted among construction professionals operating on various projects in the selected organizations. As shown in Table 6.2 below, these personnel were: Infrastructure Development Engineer (R1), Educationist and BIM Consultant (R2), Planning and Architectural Engineer (R3), Industrial Project BIM Consultant (R4), Architectural Engineer (R5), Commercial Sector Development Engineer (R6), Educationist and Project

Manager (R7), Mechanical Electrical Plumbing Engineer (R8), Real Estate Development Engineer (R9), Project Manager (R10), Project Manager at Ministry of Education Works Department (R11). These personnel are deeply involved in sharing information on projects in their respective organizations.

**Table 6.2: Level of Experience of the Respondents**

<b>Respondent</b>	<b>Job Description</b>	<b>Experience</b>
R1	Infrastructure Development Engineer	Designer using various software ranging from manual drafting to AutoCAD and graduating into Revit for infrastructure and development projects.
R2	Associate Professor	Works in construction department of the university. Also a consultant specialist in BIM and does BIM training.
R3	Lecturer and Architectural Engineer	Planning engineering and architectural engineering using ARCHICAD and practises in firms which are specialised bureaux in BIM services.
R4	Engineer	Operates in private sector and industrial projects as BIM consultant.
R5	Architectural Engineer	Design consultant in architectural engineering.
R6	Engineer	Works in commercial sector and on private projects.
R7	Educationist and Project Manager	Lectures in university's building department about every stage from the design stage to the completed building works. Also works as project manager for the university.
R8	Services Engineer	Mechanical, electrical and plumbing designer.
R9	Engineer	Real estate developer who deals with infrastructure and residential units.
R10	Project Manager	Project manager on private projects.
R11	Project Manager and Engineer	Works in Project Management Department at the Ministry of Education. This department supervises the Ministry's projects which include school and other educational buildings.

### 6.3.1 Organization Operating Sector

Questions under this theme sought to understand the sector within which the interviewees worked. The sector of construction operations varies and can be classified as public, private or both. As shown in Table 6.3 below, seven of the interviewees (R1, R3, R4, R5, R6, R9 and R10) responded based on their private sector projects while two (R7 and R11) responded based on their public sector (government) projects. Thus, two of them (R2 and R8) have been involved in both private and public sector projects.

They can also be classified based on size. The EU classifies construction organizations into small, medium and large (Proverbs and Holt 2000). The small organizations function in small areas. For example, in small organizations, R7 and R11 operate in small areas locally, while in medium-sized organizations, R1, R3 and R9 operate at national level within Saudi Arabia. The large organizations cover large areas and also operate at international level across the Middle-East countries. For example R2, R4, R5, R6, R8 and R10 operate in these large organizations working on large projects. However, some respondent are involved in projects of different sizes. For example, R11 emphasized that as projects from the Ministry of Education are designed according to model, place and need, these criteria form the basis for being involved in all forms of projects.

**Table 6.3: Operating Sector of the Interviewees**

S/N	Organization Operating Sector	Frequency of Suggestions	Interviewees (Experience In Organizations)
1	Private Sector	7	R1, R3, R4, R5, R6, R9, R10
2	Public Sector	2	R7, R11
3	Private and Public	2	R2, R8

Table 6.3 shows that the majority of these respondents who are involved in BIM application are working in the private sector. The government of Saudi Arabia therefore needs to introduce Building Information Modelling (BIM) among its workers to achieve a smooth and successful implementation within a government-controlled environment. The fact that most of the construction projects are owned by the Saudi Arabian government means that the government will also have a major role to play in enforcing the application of BIM in its projects and ensuring compliance with BIM implementation requirements among both private organizations working on government projects and also the government works departments in

various ministries and government agencies. These projects range from infrastructure development to consultancy services, commercial development, mechanical and electrical works, residential development and industrial projects.

Table 6.4 below shows that most of the interviewees from different organizations are involved on large projects. This shows that large budgets are involved on these projects which make the successful delivery of these projects paramount.

**Table 6.4: Size of Organizations Where the Interviewees Work**

S/N	Size of Organization	Frequency of Occurrence	Interviewees
1	Small	2	R7, R11
2	Medium	3	R1, R3, R9
3	Large	6	R2, R4, R5, R6, R8, R10

Table 6.4 above shows that 50% are working for large organizations, 32% for medium while 18% for small size organizations.

#### **6.4 SHARING OF PROJECT INFORMATION AMONG PROJECT TEAM MEMBERS**

This section presents responses to the question: how do you communicate and share construction project information with the different members of the project team members? The interviewees were asked to indicate the means used for sharing project information among the project stakeholders on projects they had previously been involved in.

As shown in Table 6.5 below, in terms of sharing project information among project team members, R1, R2, R4, R9 and R10 use both papers and computers, while R6, R7 and R11 use papers largely as a means of sharing information. R3, R5 and R8 use computers to share information among project team members. According to R1, information is shared “*100% by email because it is the easiest thing for records sake, for the future also. It is proof that I have already informed this person on so and so date*”. On the other hand, R11 argued that their organization uses computer very little and depends largely on paper as a means of communication on projects. R6 is also of the view that “*most contractors use hardcopy of documents to exchange information*”. Therefore, traditional process of sharing information is mostly adopted by the ministries which include two dimensional diagrams and time wasting is usually recorded on projects.

Generally, the interviewees understand the importance and urgency of sharing information among project team members in order to enhance better project performance. According to Bew and Underwood (2010), with the use of BIM, project team can come up with innovative ideas and solutions by sharing information prior to any issues which may increase the project costs. This can only be achieved with highest collaboration and teamwork between the parties of the construction project. Therefore, collaboration within different stakeholders and parties associated with the project is a core benefit of BIM usage.

**Table 6.5: Means of Sharing Information**

S/N	Method of Sharing Project Information	Frequency of Suggestions	Interviewees
1	Traditional (paper)	3	R6, R7, R10
2	Modern (computer)	3	R3, R5, R8
3	Mixed (traditional and modern)	5	R1, R2, R4, R9, R11

Information sharing, as seen in Table 6.5 above, shows that mixed methods are widely used by most organizations. According to stage 4 of the RIBA Plan of Work (2013), output and information distribution (which are mainly via a mixture of both traditional and modern methods) are termed level zero of BIM. This is contrary to the NBS National BIM report 2014 (NBS 2014) which believes that UK organizations in the construction industry have moved ahead of this level. It can also be concluded that 2D, which is the traditional method of design, is still widely accepted in Saudi Arabia. R3, R5 and R8 were opposed to the present way of sharing information, and indicated that nowadays Saudi Arabia's construction industry should practise modern means of sharing information such as digital DB. Simple software, such as Excel, has been used by the various organizations. AutoCAD is also not new to these organizations and has been in use over the years. However the collaboration and communication environment requires more efforts to be fully implemented. As it can be argued that paper-based means of sharing information is ever so gradually being phased out in the construction industry of Saudi Arabia. R11 argued that *"sharing information on projects comes in two approaches (process and technology) and ...[it is] technology [that] should be adhered to rather than the process"*. It can be concluded from Table 6.4 that the mixed method of sharing project information, which is widely used by the organizations, will

help to ease the introduction of BIM to the industry. People using old methods will gradually be introduced into BIM through regular training.

## **6.5 UNDERSTANDING OF BIM IN RELATION TO THE ORGANISATION**

Research participants were asked to explain and indicate their level of understanding of the subject of BIM and the perception of BIM in their respective companies. Several types of software, such as AutoCAD, Revit, MicroStation, Drafting and ARCHICAD, have been used in the construction industry for the purpose of passing on information on projects. BIM comes in as a total information package which helps to solve many problems on site during the construction stage.

In terms of their understanding of BIM and the awareness of BIM to their organization, all the interviewees had an understanding and knowledge of the importance of BIM although their level of understanding differed. As shown in Table 6.6 below, four of the interviewees (R1, R3, R7 and R8) had an understanding of BIM, as they had received some level of training on how to use the software and were currently using BIM on projects in their organization where it had helped to avoid construction problems and save time during construction.

Whilst R2, R4, R6, R10 and R11 all had an understanding and were aware of the importance of BIM to their organization, none of their organizations were using BIM in their projects. This is slightly reflected in a survey conducted by BuildingSmart (2011) regarding BIM awareness in Middle East, which revealed that in case of BIM adoption, GCC countries are still lagging behind the global trend. Similarly, according to Matarneh and Hamed (2017), the lack of BIM standards and policies of BIM implementation, lack of BIM awareness and lack of knowledge about BIM's benefits among the construction industry stakeholders and the lack of demand from clients and construction firms are among the critical challenges in adopting BIM.

According to R6, *“At the beginning I thought we were implementing BIM but what I understood later once I had studied for my Master’s degree in the UK was that we are not implementing BIM but we are dealing with central information storage and management, which only the staff of the company can access”*. Similarly, R11 suggested that the lack of use of BIM and regular adjustments made on projects by the Ministry has led to delays in delivery of projects and also delays in payments due to contractors. However, R5 and R9

both had a low level of understanding and awareness of the importance of BIM and their organizations were not using BIM for their projects.

The interviewees understood BIM as a process of sharing information on projects which brings many benefits, such as retrieving records for future purposes, and also helps to reduce construction problems on site. They had an understanding of the technology but saw implementation and integration of the process as a challenge to the industry.

**Table 6.6: Understanding of BIM**

<b>Understanding of BIM</b>	<b>Frequency of Suggestions</b>	<b>Interviewees</b>
High awareness and understanding of BIM	9	R1, R2, R3, R4, R6, R7, R8, R10, R11
Low awareness and understanding of BIM	2	R5, R9
Understanding of the importance of BIM to the industry	9	R1, R2, R3, R4, R6, R7, R8, R10, R11
Users of BIM	4	R2, R3, R7, R8

As shown in Table 6.6 above, R5 and R9 were the only respondents who had a low understanding about BIM, while R4 argued that BIM is seen in the construction industry as a visualization tool rather than an information management tool and it occurs at the first stage of BIM. However, despite the mainly high awareness level and understanding of the importance of BIM to the construction industry from the respondents, the majority of the organizations are yet to put into practice the full use of BIM on their projects, as they claim that the initial cost of installing the software and the training it will require for personnel to become acquainted with the software is the major challenge to BIM being practised by the various organizations.

## **6.6 FEARS OF ADOPTING BIM IN THE CONSTRUCTION INDUSTRY**

According to the Oxford online dictionary (2018), fear is defined as “*a feeling of anxiety concerning the outcome of something*”. Construction organizations may have fears in adopting innovations and changes, for instance due to the risks involved or cost associated with the innovations. However, these fears may not necessarily hinder or stop the company from adopting the changes. The participants in this research were asked to indicate whether



the fear of adopting BIM as a new technology had an influence on the use of BIM in their companies.

A number of fears have been demonstrated by various organizations in the Saudi construction industry towards the adoption of BIM, and although all the interviewees are of the opinion that BIM is a new technology in the construction industry, there is a perceived fear towards the adoption of this new technology. These fears are about training, new software, lack of technical support, initial cost of installation, lack of knowledge of BIM, lack of qualified personnel, misunderstanding of BIM and running costs. This indicates that the views of the research participants in relation to their perceived lack of qualified personnel, initial cost and lack of the training required for BIM were likely to influence their adoption of BIM.

As shown in Table 6.7 below, R1 and R10 were of the opinion that BIM is a new technology with complex software for the construction industry and the need for upgrading is imminent and they also feared that it might fade out with time if there was no demand for it. R4, R6, R7, R9 and R11 all indicated that there were fears in adopting BIM in the construction industry, but lack of knowledge and of qualified personnel were the major ones they identified. R4, R5, R7, R8, R10 and R11 mentioned the initial cost and running costs of the technology as their organizations' major fears over BIM, while R2, R5 and R10 focused on the cost of training personnel in this regard. In contrast to all of these, R3 identified no fear in the adoption of BIM to the organization because was not new to the organization and had been used by it for some time.

Lack of awareness of BIM may be the factor that led to fears of its adoption. As mentioned by R8, *"Maybe it is because we haven't had experience [of it] before. That could be the main reason – no one knows how to use it, how it extracts the information and how to manage the BIM itself."*

**Table 6.7: Fears of Adopting BIM**

S/N	Fears of Adopting BIM	Frequency of Suggestions	Interviewees	Ranked by Frequency
1	Training of personnel	3	R2, R5, R10	3 <sup>rd</sup>
2	Initial cost and running costs of the software	6	R4, R5, R7, R8, R10, R11	1 <sup>st</sup>
3	Lack of knowledge	5	R4, R6, R7, R9, R11	2 <sup>nd</sup>
4	Lack of qualified personnel	2	R4, R7	4 <sup>th</sup>

5	Change	2	R1, R10	4 <sup>th</sup>
6	Client demand	1	R4	7 <sup>th</sup>
7	Regulations for imposing BIM	2	R6, R9	4 <sup>th</sup>
8	Change of government rules	1	R9	7 <sup>th</sup>

From Table 6.7 above, the initial cost and running costs as suggested by R4, R5, R7, R8, R10 and R11 are ranked first as the major fear encountered in the adoption of BIM by the organizations. R8 felt that “*application of BIM means spending lots of money for any project. With BIM you have to increase the project cost, to make a profit*”. Therefore, the organization sees the BIM application as a threat to their profit margin.

The cost issue was closely followed by lack of adequate knowledge of the software and then by the training of personnel. The view of R11 was that “*BIM has been misunderstood and lack of awareness of what can bring to the industry is a factor to be considered*”. The respondents were of the opinion that once the first three ranked items were eliminated, BIM would be easily adopted in Saudi Arabia’s construction industry. Those who selected initial cost and running costs as the main fear encountered were also of the opinion that the government should encourage organizations to use BIM on their projects, and they suggested that once the government makes it compulsory for all projects to be executed by BIM, organizations would have no choice but to adhere to it. According to R2, “*the Saudi government should make [BIM] compulsory for getting contracts, like in Emirates. As you know, in Dubai in 2014, the government of Dubai forced the companies to implement BIM for all their projects.*”

The solution proposed in response to the lack of adequate knowledge of BIM was that organizations and the government should make it a routine procedure to help their personnel in acquiring knowledge of new developments in the industry.

The training of personnel was also seen as paramount and it was suggested that conferences and workshops should be held regularly to ensure that personnel are up to date on knowledge about BIM. R6 stated, “*I will invest in training individuals in the hope that it will prove to have value. This application should be supported with training throughout because spreading knowledge of BIM will ensure its wide implementation in organizations*”.

## 6.7 MAIN BARRIERS TO ADOPTION OF BIM

Interviewees were asked about the main factors they foresaw or had experienced as barriers to the adoption of BIM in the Saudi Arabian construction industry. According to the Oxford online dictionary (2018), a barrier is “a circumstance or obstacle that keeps people or things apart or prevents communication or progress”. In this case, these are factors that prevent construction organizations from adopting innovative technologies like BIM in their organizations.

As shown in Table 6.8 below, according to the responses from the interviewees, there are many barriers to BIM adoption, despite the benefits it brings to the industry, and these barriers are keenly felt by various organizations. They include the fear of change, cost of implementation, team culture, lack of knowledge, legal and contractual issues, client awareness, government rules and regulations, and training and lack of manpower. Similarly, according to survey findings from BuildingSMART (2011), the main barriers to BIM adoption are lack of experience and skilled staff who are knowledgeable and equipped in using BIM, cost of BIM implementation, lack of education and lack of proper training in using BIM, and very low level of knowledge and understanding about BIM usage.

**Table 6.8: Barriers to The Adoption of BIM**

S/N	Main Barriers To BIM	Frequency of Suggestions	Interviewees
1	Team culture	5	R2, R4, R5, R7, R9
2	Client awareness and requirements	2	R4, R8
3	Legal and contractual issues	6	R2, R4, R5, R7, R9, R11
4	Training and lack of manpower	All of them	R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11
5	Cost of implementation	All of them	R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11
6	Lack of strict government rules and regulations	1	R6
7	Fear of change	All of them	R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11

From Table 6.8 above, it can be observed that R2, R4, R5, R7 and R9 identified team culture as one of the key barriers to the adoption of BIM by organizations and they also stated that legal and contractual issues involving BIM are not understood. It was discovered that different nationalities of personnel are used in executing projects in Saudi Arabia. According to R2, *“the team culture is very important, especially at this time when we have different nationalities doing construction work in Saudi Arabia”*. This can have a major effect on project information because the introduction of BIM would attract a new method of work but would not affect communication because BIM is an improved means of communication about projects. It was also suggested that once collaboration and communication is introduced team culture improves.

R4 and R8 identified clients requirements as the main barrier, stating that once a prospective client is aware of the benefits and knows the application of BIM, that client will insist that the technology should be used on their projects. It was further stressed that since the client bears the burden of the initial cost and running costs of the software their consent is important before BIM can be adopted on any of their projects.

R6 was of the opinion that lack of motivation and lack of strict rules and regulations from the government are the main barriers to the adoption of BIM. R6 stressed that *“there is a lack of motivation on the side of the government and its various ministries and agencies”*. In other words, there are few or no motivational measures to make individuals and construction organizations adopt BIM. Furthermore, R3 and R8 held the view that team culture and contractual issues do not really have a direct impact on the adoption of BIM: they suggested that culture has nothing to do with the adoption of BIM since it is a general language that is used in running the software and also expatriates have carried out projects in Saudi Arabia using BIM and these were successful.

Suggestions were also made by the respondents that workshops, conferences and short training courses should be organized by the government and organizations to educate personnel in the industry. According to R1, *“For sure, if you are going for anything, you need to have the basic knowledge. You need the basic things to know what it is about. What does it do? What does it create? You need to know everything about it. So, for that reason you need something compulsory, for example a conference”*. In cases where the organizations cannot afford the cost of training of their personnel, the government should subsidise such training so that it can be affordable by the various organization. This will serve as a means of

motivation and encouragement for both the organizations and the personnel to adopt the use of BIM.

## **6.8 STRATEGIES FOR BIM ADOPTION**

According to the Oxford online dictionary (2018), strategy is “a plan of action designed to achieve a long-term or overall aim”. The research solicited ideas from the participants on what they considered as strategies for achieving a successful adoption of BIM and realising the benefits of BIM on a long-term basis. The strategies proposed by the interviewees for its successful adoption in Saudi Arabia include: collaboration between government and professional bodies towards adopting BIM, creation of binding rules on construction organizations and government works departments on BIM implementation, creation of a separate department or agency to guide or support the application of BIM in both private and public sector projects cost-free, creation of BIM task group and alliance, training of personnel, identification of main actors and champions, increasing awareness level of the benefits of BIM, including BIM in the curriculum for students at colleges and universities that teach engineering and architecture courses, government enforcement of the use of BIM on projects, and conducting conferences and workshops.

As shown in Table 6.9 below, R1, R2, R3, R5, R6, R7 and R9 all agreed that the creation of new rules guiding BIM in the industry would help to enhance the adoption process, and to support these new rules, R3, R4, R5, R7, R9 and R11 believed that a BIM task group and alliance is urgently needed. For all these to be achieved, R1, R2 and R11 believed that there should be collaboration between the government and various professional bodies involved in the industry to ensure that BIM is used, whilst R1, R2, R10 and R11 further stressed that the government is in a better position to enforce the use of BIM on every government project as this has been practised in some European countries. According to R2, *“I think that is what actually happened in the UK, so if you want Saudis to adopt BIM, you need someone to enforce it like the Saudi Council of Engineers, for example”*. However, R9 observed that enforcement of a BIM task group may be difficult, due to the nature of the Saudi industry.

To achieve enforcement, R4, R6, R7, R8 and R9 are of the opinion that a separate department such as a government ministry or specialist government BIM department, should be created to handle the affairs of BIM and to ensure the successful integration of BIM. They also pointed out that the new department would also need to be given the autonomous power to oversee all that pertains to BIM to ensure that it is a success in Saudi Arabia. However, R2

and R10 believed that a separate department is not needed but the BIM proposal should be integrated into the existing department so that everyone in the industry can be carried along. *“You need to develop your existing department to support BIM application”* R2 suggested.

The main actors in carrying out these strategies are the government and professional bodies. R5 and R8 believed that the professional bodies are more involved in the execution of projects while R2, R4, R5, R6, R7, R8, R9, R10 and R11 viewed the government as the main actor since they set the standards and rules that guide projects in the country. Looking at the government as the main actor in the construction industry in Saudi Arabia, they are mainly involved in the setting of policies, standards and rules that will affect the industry, and R11 suggested that *“it must start from the higher authorities. This gives them a better chance of ensuring that BIM is implemented and also used by the industry”*. Similarly, Smith (2014) found that government support and collaboration with construction industry leadership is necessary in order to implement BIM successfully. For instance, in countries like the UK and USA, the government has mandated the use of BIM in publicly funded projects. Furthermore, Quek (2012) also identified the setting of national and global standards for BIM as a key strategy for BIM implementation.

Increasing the level of awareness, conducting conferences and seminars, and increasing the knowledge of BIM were considered by the respondents to be key strategies to BIM adoption. For instance, according to R10, *“the first strategy if the government wants the construction participants to implement BIM is to increase the level of knowledge and the awareness”*. Education and training on BIM and strategic planning and standardised government policies are also a strategy suggested by Al-Mohannadi *et al.*, (2013). Clients’ requirements and owners’ adoption are considered by R5 and R8. *“You need the client to buy in and specify it as part of the requirements in the project”* R5. R8 believes that *“to achieve this, you need to change the client’s mindset”*. Therefore it can be established that BIM implementation starts from the client, so the client is one of the main players in implementing it.

One of the respondents R7 suggested that presenting case studies to show various benefits enjoyed and challenges encountered and how the latter were resolved by using BIM on previous projects executed where BIM is practised, is a means of motivating and creating more awareness among clients, organizations and various personnel in the industry. For instance, Yoon *et al.*, (2015) suggest that free access to BIM product archives and online-

based BIM building product information are needed in order to facilitate and motivate the construction professionals.

As shown in Table 6.9, the enforcement creation of new rules and standards by the government as the main actor was ranked first among strategies to be carried out to ensure the adoption of BIM. This shows that the majority of the work concerning strategies on BIM adoption lies with the government and they should produce a time frame for mandatory BIM implementation on construction projects in Saudi Arabia.

To assist the government in achieving their objectives it was suggested that the creation of a BIM task group and alliance and forming collaboration with BIM experts would help government in putting adoption of BIM on track. While R8 and R9 were pessimistic about the effectiveness of this strategy due to the cultural nature of the industry, R1 suggested that *“this responsibility could be undertaken by the Saudi Council of Engineers”*.

**Table 6.9: Strategies for Adopting BIM**

S/N	Strategy	Frequency of Suggestions	Interviewees
1	Government enforcement	4	R1, R2, R10, R11
2	Creation of separate department for BIM	5	R4, R6, R7, R8, R9
3	Creation of BIM task group and alliance	6	R3, R4, R5, R7, R9, R11
4	Collaboration between government and professional bodies in the industry	3	R1, R2, R11
5	Creation of new rules and standards for BIM	7	R1, R2, R3, R5, R6, R7, R9
6	Integrating BIM with the existing department	2	R2, R10
7	Increasing knowledge and awareness by conducting conferences, seminars and training	3	R3, R10, R11
8	Clients' requirements and owners 'adoption	2	R5, R8
9	The main actor to use in ensuring compliance (government)	9	R2, R4, R5, R6, R7, R8, R9, R10, R11
10	The main actor to use in ensuring compliance (professional bodies in the industry)	2	R5, R8
11	Including BIM as part of the curriculum for undergraduates	2	R6, R7

12	Presenting of case studies to show various benefits and challenges encountered using BIM	1	R7
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The creation of a new department separate from the existing Ministries would give a better insight into the use of BIM. A BIM manager should also be appointed just like a project manager for projects, to oversee all activities involving BIM in such projects.

It was also deduced from the interviewees that if the government took this position as the main driver of the successful implementation of BIM into the industry, as is the case in countries like the United Kingdom and Germany, it would achieve great success in Saudi Arabia's construction industry. This was further supported by their view that where the government takes on the role of main actor in the implementation process, new rules and standards should also be created for BIM with a working plan for implementing its various levels.

## 6.9 EDUCATION AND TRAINING AS ENABLERS OF BIM ADOPTION

Participants were specifically asked to indicate whether education and training were critical factors to the adoption of BIM in the Saudi construction industry. Education and training are seen as the best strategic enablers for the adoption of BIM. Considering BIM as a new technology in the construction industry in Saudi Arabia, and the fact that it is implemented at different levels, all interviewees agreed that there was a need for training and education. Although the views on this process differed from one respondent to the other, they included: BIM should be included in the university curriculum, seminars, workshops, presentations, short courses and training.

According to respondents R3, R7 and R9, BIM should be included in the curriculum of undergraduate students in colleges and universities that teach Engineering and Architecture courses to degree level. These would include the introductory aspect of BIM and also the enablers for BIM across all the implementation levels. According to R9, *“for undergraduates it is good to teach some modules about BIM application in construction”*. Similarly, R3, R4, R5, R6, R7, R9, R10 and R11 generally observed that it was better for all colleges and universities that teach engineering and architecture courses, its students should be aware of the technology and have a basic knowledge of it before leaving the university, which would make it easier for them when working with BIM on projects. As BIM comes in different levels, a long period of study is required to make it easier for undergraduate students in the colleges or universities.



Considering the fact that there are some people in the industry who graduated years before the evolvement of BIM, it was also agreed that courses should be put in place to train people on the job all levels of BIM. R1, R2, R4, R5, R9, R10 and R11 all supported the use of short courses, since at present it is not used everywhere in the world as a means of training people on the job. However, R9 suggested that *“for those graduates who are already working in construction, they can receive some training on BIM in their related fields that matches the needs of their companies which should also support their employees in taking such courses”*.

Workshops and conferences were also seen by all the respondents as a means of passing on knowledge and awareness of BIM to people already practising in the industry before the introduction of BIM. R1, R3, R6, R7 and R10 agreed that this should be done on a regular basis so that all levels of BIM can be understood to the fullest by the personnel. They also emphasize that this training should be free for various staff so as to encourage them to adopt the use of BIM on their projects.

R1 and R2 were of the opinion that both government and organizations should send their staff regularly on training and also for workshop on a regular basis so that they can be best equipped with the knowledge of BIM. According to R2, *“the construction organization and also the government should help in the training. And they should have at least 2 training courses like in each month and pay the price for this training. It should be supported by the government and they should force the contractor, consultants and the project owners to send 2 employees each month to learn”*.

It was concluded that BIM should be given a trial in the industry in Saudi Arabia because it is a useful technology and the application should start before the construction stage of any project.

## **6.10 IMPLICATIONS OF THE FINDINGS**

The aim of the interviews was to explore the level of awareness of BIM and the barriers encountered in the adoption, provide the best strategies to be used in the implementation of BIM, and create awareness in the construction industry in Saudi Arabia. Findings from the interview and questionnaire survey will be then used to develop a strategic framework for BIM adoption in Saudi Arabia to address the aim of the study.

Rules and standards are to be created for BIM in the construction industry and a level of compliance should be ensured by the government as practised in countries such as the UK and Germany. To support this, a BIM task group and alliance should be formed. To further

strengthen the awareness level, BIM should be introduced into the curriculum of students at the Colleges of Engineering and Architecture, who should be taught the different levels of BIM during their undergraduate programme. For personnel in the industry who have graduated from university before the evolvement of BIM, training and conferences should be made available on a regular basis and personnel should be motivated and encouraged to participate in these activities.

From the research findings, key areas have been identified to help in the adoption and implementation of BIM in the industry. These areas are briefly discussed below. (A detailed discussion of the key implications of the research results from interviews and questionnaire are presented in chapter 7 which deals with the development of a framework for BIM implementation for the Saudi Arabian construction industry).

#### **6.10.1 The Need for Developing a Foundation for BIM Adoption and Implementation and the Role of Government**

As seen from the research findings, adopting and implementing BIM requires a good foundation that would enable and positively impact on the adoption and implementation of BIM. The foundation would need to clearly identify and promote an agenda for the industry and also set in place the resources needed. As seen in section 6.4, the sharing of project information among team members is a key requirement for implementing BIM. The foundation developed for BIM should take this into consideration and also the industry should have a more collaborative approach. From the results, it is quite clear that government has a key role to play in the process. As seen from the analysis, government's role will be in the form of policy to support the process and investments into BIM considering the cost implication. As shown in Table 6.8, legal and contractual issues are some of the main barriers to implementation. The lack of government rules has also been identified as a barrier to BIM implementation. Taking all these into consideration, BIM implementation and adoption would require government involvement if the process is to be successful.

#### **6.10.2 The Need for A BIM Task Group**

From the results discussed in this chapter, creating a BIM task group will help to spearhead government efforts to improve the performance of the construction industry through the adoption and implementation of BIM. The task group can help set the agenda, decide timelines and put in place measures to help the industry achieve its BIM objectives.

### **6.10.3 Lack of BIM Knowledge and Skills and the Need for Education**

The analysis of data also indicates that the construction industry lacks the knowledge and skills required to implement BIM. This is one of the main barriers to BIM implementation in the Saudi Arabian construction industry, and investment in education and training is required, in order to ensure the success of BIM implementation in the industry. In this regard, education and training are seen as a key requirement for the industry to achieve its aims. Due to the low level of awareness and the lack of skills in best practices to achieve BIM implementation in the industry, the educating and training of construction personnel will help to bring the industry to the level required for implementing and adopting BIM.

### **6.10.4 Collaboration and Communication**

The research findings shown that collaboration and communication are key requirements for implementing BIM. Any effort to ensure the industry adopts BIM should therefore place an emphasis on ensuring a cultural change in the way the industry communicates and collaborates. Collaboration and communication should therefore form a key part of any strategy to implement BIM.

### **6.10.5 Increased Awareness of the Benefits of BIM**

The results of this research also imply that increasing the level of awareness of the construction industry in relation to BIM and the benefits it provides will serve as a key enabler in the process. This will encourage the industry in their willingness and commitment to adopt BIM, knowing the benefits they stand to gain.

## **6.11 IMPLICATIONS OF FINDINGS FOR FRAMEWORK DEVELOPMENT**

As shown in Chapter 5 and in this chapter, the results imply that for the participants in this research there is a low level of understanding of BIM. The low awareness and the lack of collaboration in the industry, lack of legal backing for BIM adoption and the barriers to BIM implementation as presented in both the qualitative and quantitative data analysis chapters of this research imply that a systematic approach should be taken towards BIM implementation with government backing. The need for government support and investment in BIM, as indicated by the research results, forms the basis for developing a framework that ensures the necessary actions are taken to improve BIM adoption and implementation in the Saudi Arabian construction industry. The impacts of the results of this research on the development of the framework are presented in section 7.3 of this thesis.

## **6.12 SUMMARY OF CHAPTER SIX**

The interviews explored the relevance of BIM to the construction industry in Saudi Arabia and looked at the awareness level of various personnel in the industry on BIM, barriers that hinder the adoption of BIM, strategies of implementing BIM and the tools that would ensure the smooth running of all strategies identified. The findings from the interviews cut across 11 practising organizations of different sizes that operate in different sectors and work on different kinds of projects across the country. The findings identified that the initial cost of installing the software and also running costs like training were the main barrier confronting the organizations practising in Saudi Arabia. Although the majority of the personnel had heard about BIM in the past and also worked on it, the fear of having to change from the old ways of doing things posed a considerable barrier to the industry. Furthermore, the respondents were of the opinion that BIM brings many benefits to the industry, as practised in European countries and America, and so identifying the barriers and the main actors in the industry playing their key roles would help the implementation of the Technology.

However, all the benefits identified with BIM were positive in relation to the construction industry and none of the respondents was against the use of BIM on projects in the country. They only indicated their fears in adopting the use of the software, but stated that once these were addressed, all organizations would adopt the use of BIM on their projects to enjoy the benefits it brings to the industry.

The explorative study identified conferences, workshops, and development of a curriculum on BIM as the best tools to help to ensure that BIM is implemented in the construction industry in Saudi Arabia.

The chapter found that 12 strategies can help to ensure that BIM is fully implemented in the industry. The majority of these strategies were suggested by the literature and the quantitative and qualitative studies, to show the various benefits enjoyed and likely barriers encountered and how the latter were resolved by using BIM on previous projects executed both in Saudi Arabia and other European countries where BIM is a normal practice, and these strategies were suggested as a means of motivating and creating more awareness among clients, organizations and also various personnel in the industry.

The next chapter develops a framework for the industry-wide adoption and implementation of BIM, based on the results of the study.

# **CHAPTER SEVEN**

## **STRATEGIC FRAMEWORK FOR IMPLEMENTING BIM IN SAUDI ARABIA**

### **7.1 INTRODUCTION TO CHAPTER SEVEN**

Based on the results of this research discussed in the previous chapters, there is a clear indication that Saudi Arabia as a nation can benefit from the proper implementation of BIM in its construction industry. To achieve this, there is a need for a strategic approach to BIM implementation which will take into consideration the local factors within the nation, combined with best practices captured from other countries around the world where BIM implementation is at a much more developed level. This aim of this chapter, therefore, is to draw together the different elements of the framework identified in the research and to develop a strategic framework for BIM adoption and implementation in the Saudi Arabian construction industry. The chapter discusses the main issues that are likely to affect the adoption and implementation of BIM within the construction industry, steps that can be taken to ensure proper implementation, and a strategic framework that forms the blueprint for this implementation. The chapter also identifies the key parties in the process and the specific roles to be played by these parties.

The strategic framework is developed as a contribution by this research towards practice. Information for developing this framework is taken from all the stages of the research from the background issues raised in the introductory chapter to the results gathered from the collection of data.

### **7.2 DEVELOPING A STRATEGY FOR BIM IMPLEMENTATION IN SAUDI ARABIA**

Adopting BIM into any construction industry requires a proper strategy which ensures that the advantages of BIM can be achieved. As reported in Khosrowshahi and Arayici (2012), reaping the benefits of BIM is contingent upon its proper implementation at an organizational level and its integration at the construction industry level. To ensure both of these are successful, there is a need for a BIM implementation strategy which ensures an all-inclusive

approach is adopted. In developing a strategy for BIM implementation, Arayici *et al.* (2011) suggest the adoption of a socio-cultural view which considers both the implementation of technology and a socio-cultural environment that provides the context for its implementation. Smith (2014) surveyed BIM implementation in different countries and believes that the social context within which BIM is implemented plays an important role in its success. From the study by Smith, the critical factors include government and construction industry leadership. In addition to factors that will support the adoption of BIM, there is also a need to ensure that the framework for BIM implementation is comprehensive enough to cover all the relevant issues with its adoption and implementation (Jung and Joo, 2011).

Jung and Joo (2011) suggested that a strategic framework for BIM implementation should cover BIM technology, BIM Perspective and Construction Business Function, as shown in Figure 7.1 below.



**Figure 7.1: Strategic Framework for BIM Implementation**

Source: Jung and Joo (2011)

From Figure 7.1 (above), it can be seen that BIM adoption and implementation do not cover only single projects or organizations but require a construction industry-wide focus. The

strategic framework developed in this chapter considers the Saudi Arabian construction industry as the main focus.

### **7.3 COMPONENTS OF THE STRATEGY FRAMEWORK FOR BIM IMPLEMENTATION**

The results of the quantitative research helped to understand the current state of BIM adoption in the Saudi Arabian construction industry. From the results of the quantitative study, the reasons for current adoption levels as well as the anticipated barriers to BIM adoption were identified, and helped in shaping the core of the framework and in particular in understanding the general perception of people in the industry and the gaps in their understanding of BIM. Based on the results, recommendations for BIM education and training were made central to the framework. The outcome of the quantitative research, in particular identifying the low level of familiarity with BIM, helped to understand the need to improve upon the education of people in relation to BIM. Results from the reasons for the use of BIM also indicated that BIM was not a key requirement either by legislation or from clients and these were two of the reasons for its low adoption. Based on this, the framework made recommendations for government action to make BIM a requirement for construction projects.

The results from the qualitative research also had a considerable impact on the development of the framework. From the outcome of the qualitative study, it was identified that the fear of adopting BIM due to the training requirements, the lack of technical support and the installation costs were all taken into consideration as key areas of the framework. Due to the perceived lack of both technical support and qualified personnel, the framework developed for BIM adoption and implementation recommends BIM as a key requirement in the training and education of construction professionals. Lack of government regulation was also found to be one of the main barriers of BIM implementation, according to the results of the qualitative research. The development of the framework took these outcomes into consideration and recommended the setting up of a BIM task group to help in the development of legislation relevant to the Saudi Arabian construction industry.

In developing a strategy for BIM implementation in the Saudi Arabian construction industry, this research adopted the periodic table for BIM implementation developed by the National Building Specification (NBS, UK) which covers nine key areas or components: Strategy,

Foundations, Collaboration, Process, People, Technology, Standards, Enabling Tools, and Resources. These areas relate to the ones identified in the analysis of data presented in the previous chapter (see section 6.10 for the implications of the findings and key areas identified). The choice of the periodic table as the basis for developing the framework for BIM implementation in Saudi Arabia was based on the outcome of the research and the links between the aim of the research and the elements of the periodic table. From the results of this research, it was identified that BIM implementation in Saudi Arabia currently did not have a strategic orientation and there was no clear road map to be followed. The qualitative research also suggested that the fears of the industry in terms of lack of qualified personnel and lack of finances and resources were closely aligned with the provisions of the periodic table, which was therefore adapted for this research as it covered the key areas required for BIM implementation. Even though this periodic table was designed for company level BIM implementation, it contains information that can be adopted and modified for a national level strategy.

### **7.3.1 A National Strategy for BIM Adoption and Implementation**

To have a strategic approach to BIM implementation, the first step is to define a national framework for its implementation which takes into account the main aim for this in the country. The framework developed in this chapter is a strategic one, which seeks to make clear how the efforts of specific individuals can be allied with the intention of achieving the best outcome by covering significant and meaningful sequence of activities and target measures which facilitate key efforts to implement the strategy. As in many other countries, the construction industry in Saudi Arabia is burdened with issues of project management which lead to many projects either not being completed at all, or being completed late, over budget, and of poor quality. As discussed in Section 6.8, these problems can be managed or controlled to a large extent if there is collaboration and a common environment for the sharing and distribution of information during projects. As well as using education and training as a tool for BIM adoption (see sections 6.10.3 and 5.3.2), from the study conducted it has been identified that BIM adoption and implementation in Saudi Arabia will require the setting of targets, the enactment of policy, and the implementation of a body tasked with the role of overseeing BIM adoption and implementation. As part of the strategy for this adoption and implementation in Saudi Arabia, three main areas are expected to be targeted: BIM technology (which focuses on standards, utilization and property), BIM perspective (which targets the construction industry, and ensures BIM adoption trickles down to the



organizations and project level implementation), and construction business function (which should cover all the parties in the construction industry from design professionals to project managers and facilities managers).

### **7.3.2 Foundations for BIM Adoption and Implementation**

As gathered from the research, the success of BIM implementation in any organization or construction industry is dependent on the foundations built to support data production, distribution and management of construction information. As BIM is about information sharing and management among different professionals in a common environment, the need for a strong foundation which supports such activities is a very important one. This requires a considerable amount of collaboration in the construction industry, if a strong foundation is to be built. From the data gathered by this research, the current approach to information sharing in the Saudi Arabian Construction industry is via paper (hard copies of documents), computers (emails), or a mixture of the two (see section 6.4). Comparing the means of sharing information in the construction industry to other developed countries, the need to build a strong foundation for information sharing becomes pre-eminent. Section 6.10.1 also suggests that a strong foundation is needed for adopting and implementing BIM.

As part of the foundation required for successful BIM implementation, there is a need for a framework for capturing digital information and exchange flows from the inception of projects through to the procurement and construction stages. As discussed by Jong and Joo (2011), the essence of having a framework is to “*guide research efforts, to enhance communications with shared understanding, and to integrate relevant concepts into a descriptive or predictive model*”. For a national BIM implementation strategy, a practical framework is needed in order to set the stage for establishing common goals and enhancing processes that can lead to the achievement of such goals. The need for such a framework for the Saudi Arabian construction industry will help to set the standards to be met and create a platform for auditing and measuring the BIM readiness of the construction industry. This has the potential to help in identifying the needs of the construction industry in terms of BIM readiness and the kind of interventions required to make the best of BIM implementation.

One of the keys to implementing BIM is having common methods shared among the participants in the construction industry. The adoption of common standards for all the stakeholders within the industry will go a long way to ensuring common methods are adopted in producing building information which is easily accessible to all parties as stated in (section

5.4.7). The term “Common Standards” refers to common terminologies which are understandable to all parties in the construction industry. For a national level BIM implementation, it is very important to have common standards by adopting standards that have been developed for such purposes, such as an information delivery manual (IDM) or an international framework dictionary (IFD). Findings from the literature suggest that the private sector plays a key role in advising the public sector and even the government in developing a national BIM application agenda (Bin Zakaria *et al.*, 2013). Similarly, section 5.2.1 of the Quantitative Analysis chapter shows that the private sector needs to be involved in developing the BIM agenda.

Information from countries where its implementation is well developed suggests that the procurement route has an impact on the success of BIM. Due to the need for change in the practices of the parties in a BIM environment, procurement should be taken into account in developing a strategy for implementation. A supportive BIM procurement arrangement should seek to create a contractual framework that ensures a collaborative arrangement.

Having a strategy for BIM also requires ensuring that the parties or stakeholders have the qualities and skills needed to implement BIM. For an industry-wide implementation of BIM, this requires an effort to determine what skill sets are required for BIM implementation throughout the construction industry and to ensure that such skills are available through the provision of training.

### **7.3.3 Collaboration Needed for BIM Implementation**

As mentioned earlier, collaboration for BIM implementation is very important for success. The main idea behind BIM is to ensure a common environment where parties can collaborate on projects. As discussed by Arayici *et al.* (2011), the need for collaboration for BIM implementation covers both technologies for collaboration and socio-cultural behaviour change in the construction industry. This requires a change in management approach that can involve all the stakeholders in the construction industry. Successful BIM implementation requires the development of an enabling culture where people understand the need to work together utilizing digital tools to their advantage. This also requires a change in the processes adopted in the construction industry, including procurement methods such as design and build, partnering or alliancing, prime type contracting, and private finance initiatives, all of which are known to support BIM implementation.

From Section 6.10.4, it can be seen that collaboration and communication are key requirements in the process of adopting and implementing BIM. The research results reveal that the level of collaboration and communication among the parties in the construction industry is low and needs to be improved for the purposes of adopting and implementing BIM. Collaboration for the purposes of BIM is also made possible by having common standards and inter-operable features throughout the construction industry.

#### **7.3.4 The Need for a Process that Supports BIM Adoption and Implementation**

BIM adoption and implementation is about changes in processes. Changing processes to support this adoption and implementation begins by first assessing the current situation as well as the needs of the construction industry. As has been captured in this research, current processes within the Saudi Arabian construction industry will need to be improved to ensure that BIM adoption is successful. For this industry, processes involved in sharing information, plans of work and a common data environment are some of the areas that need to be improved to ensure a successful BIM implementation. In addition to the improvement in these processes, there is a need for a change in information management processes, due to the amount of information generated for the purposes of BIM. Just as in other countries, change in processes can be made possible with government intervention in the Saudi Arabian construction industry. As shown in Table 6.9 (see section 6.8) adopting BIM in Saudi Arabia may require the creation of a BIM task group that will oversee the change in processes in the construction industry and government, thereby ensuring compliance with changes. Sections 6.10.3 and 5.4.9 also indicate that currently the country's construction industry does not have the requisite knowhow in terms of skills and the processes involved in implementing BIM. This is an area which needs to be improved through education and training of parties in the construction industry.

#### **7.3.5 The Role of People in the Adoption of BIM**

As social and cultural elements play a key role in the implementation of BIM, it is essential to ensure that the people involved in the process have the right attitudes towards supporting BIM implementation. Just as a change in processes will facilitate BIM implementation, a change is needed in the attitude of the people involved (stakeholders) towards ways of doing things in the construction industry. This also involves ensuring people are equipped with the required skills. As shown in Table 6.9 (see section 6.8), increasing the awareness of people in the construction industry and including BIM as part of the curriculum for undergraduate students are changes that are expected to improve the capacity of the stakeholders. There is a

need for investment in the construction industry with an emphasis on support for their soft skills improvement. As shown in the results in sections 5.3.2 and 5.3.3, the awareness and use of BIM by people in the construction industry is very low. A strategy for BIM should therefore put people at the forefront of the process and ensure they are equipped with the right resources and knowhow.

Table 5.2 also shows that most of the participants who could help promote BIM related practices in construction companies are Project Managers and Directors. According to section 5.2.3, they are the key players in the KSA construction industry.

### **7.3.6 Technology Required for Adopting and Implementing BIM**

The general notion of BIM is that of a new technology. In terms of technology for BIM adoption and implementation, there should be an investment in BIM related software and hardware, as well as infrastructure. Changing current processes in the Saudi Arabian construction industry to implement BIM requires investment in technology as well as training people to become conversant with the use of such technologies. A major part of the technology requirements for BIM implementation is the development of infrastructure at the national level or by the key players in the industry, which will have the capacity to store the large amounts of data (information) generated through the process. Ensuring effective communication between several devices is an importance part of the success of BIM implementation.

### **7.3.7 Standardization of Processes Within the Industry**

As mentioned earlier, standardization is an integral part of BIM adoption and implementation and should be considered in developing a BIM strategy. Standardizing and adopting standardized methods of producing building information greatly help in the implementation of BIM in the construction industry. Standardized library objectives for architects and designers, standardized procurement routes, standardized protocols for collaborative working, and standard design management systems are some of the key requirements in this regard. In other words, for the construction industry to improve and be in a good position to adopt BIM, standardization should be a key requirement. In terms of standardization, it is important for the industry to have common terms and reference libraries that can serve as a common source of information for all the key players in the industry. The use of standard reference libraries and reference points also provides a common means of communication between all parties which then can lead to the collaboration required for BIM implementation.

### **7.3.8 Enabling Tools That Support BIM Adoption and Implementation**

In terms of tools for the successful implementation of BIM, the Saudi Arabian construction industry needs to be supported by enabling tools, which will ensure the industry has the capability to implement BIM. This includes the availability of BIM toolkits on projects that will ensure clear roles are marked and identified as well as providing help to manage responsibilities. These tool kits are expected to serve as a source of information for the parties in the industry who will be involved in BIM implementation. Enabling tools include analysis tools, costing tools, tools for reviewing and checking BIM models, tools for producing specifications and authoring tools for generating data for multiple users. These tools form part of the key areas that require investment, as discussed in section 7.3.6 regarding technology required for BIM implementation.

### **7.3.9 Resources to Support BIM Adoption and Implementation**

One of the requirements for effective BIM implementation is the availability and the use of resources from different means, including BIM users from around the world. Survey reports from different countries and projects, and communities of practice and social media serve as good resources to help different groups to make the best of their BIM implementation plans. In the case of the KSA construction industry, there is an advantage in obtaining resources from other industries or countries where BIM adoption and implementation is at an advanced stage. Such resources are likely to help in providing answers to many of the questions that might arise in the implementation of BIM in the construction industry. These resources can also serve as part of the strategy for BIM education for stakeholders within the construction industry. Communities of practice, from online users to recognised bodies all over the world, can be contacted for practical problem-solving and experience in terms of BIM implementation. The framework should ensure the availability of such resources which will have a positive influence on the rate of adoption and the extent to which benefits can be achieved.

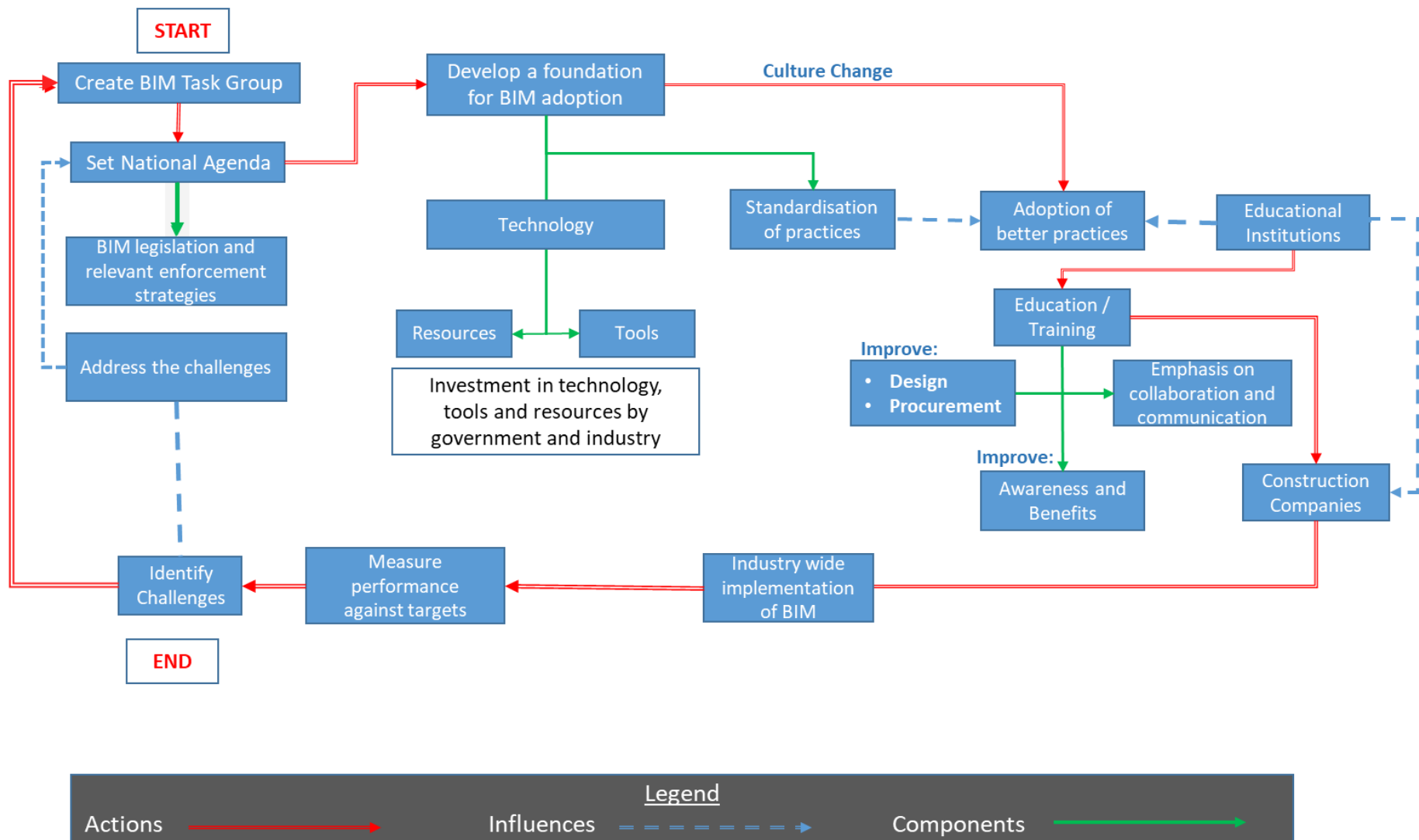
## **7.4 A STRATEGIC FRAMEWORK FOR BIM IMPLEMENTATION IN THE SAUDI ARABIAN CONSTRUCTION INDUSTRY**

From the discussion above, it has been identified that implementing BIM in the Saudi Arabian construction industry requires an effort by all the stakeholders in the industry, including the government, with investment in people, processes and technology. Based on the results of this research and information from the NBS periodic table of BIM implementation, a national strategy for BIM implementation for the construction industry in

Saudi Arabia has been developed as the contribution of this research. This section provides the framework for BIM implementation followed by instructions on how this can be effectively implemented.

In developing the framework for implementing an industry level strategy for adopting BIM, the results of this research were taken into consideration. This covered key areas such as: the level of BIM awareness within the construction industry; current information-sharing practices within the construction industry; fears about implementing BIM; barriers to the implementation of BIM; and strategies for adopting BIM in the Saudi Arabian construction industry based on the nature of the industry.

The national framework developed for the adoption and implementation of BIM is shown in Figure 7.2 below.



**Figure 7.2: A Framework for Implementing BIM in the Saudi Arabian Construction Industry**

### **7.4.1 Key Groups in the Implementation of the Strategy**

As shown at the beginning of this research (see Chapter 2), the Saudi Arabian construction industry is burdened with issues of projects not meeting the success criteria in relation to time, quality and cost, and it is the nature of the industry that has largely contributed to this. In order to establish a national strategy for BIM adoption and implementation, three key groups are identified: government, the construction industry and educational institutions.

#### **7.4.1.1 Government**

Setting a national agenda for BIM implementation begins with the willingness of the government to have an impact on the construction industry. Government influence comes in three main areas: setting up a national agenda for BIM, developing a BIM Task Group, and investing in BIM for the benefit of the construction industry. The government therefore needs to set up a Task Group for BIM implementation by liaising with the construction industry and even partnering with personnel from other countries with experience in BIM implementation. The purpose of the Task Group is to ensure that a clear pathway and agenda for BIM is developed for the construction industry. This will help in laying the foundation for the national adoption and implementation of BIM. The BIM Task Group will set the agenda and develop timelines for achieving key milestones. The group will also be responsible for measuring the performance of the construction industry in terms of BIM implementation and meeting of the targets. As part of the performance measurement, the BIM Task Group will also seek to identify the challenges to the implementation of BIM within the construction industry. Identifying the challenges will require partnering with educational and research institutions to investigate issues.

The government needs to enact legislation where appropriate, with the resources required for enforcing such legislation. Section 5.3.4 indicates that the use of BIM is not a key requirement for awarding contracts and executing projects in the Kingdom of Saudi Arabia. Therefore, in order to encourage its application in the construction industry, the government should make it a key requirement for awarding its contracts. As in countries with an advanced status in BIM implementation, setting up this legislation will help in standardizing practices and processes within the construction industry and will push construction companies as well as all other parties in the process to adhere to standards or common practice. As identified from the analysis of data, the lack of legislation is one of the challenges to BIM adoption and implementation in the Saudi construction industry.



The third mandate for government in line with the BIM strategy is the investment required in order to ensure a good foundation is developed and laid out for BIM adoption and implementation. Due to the level of investment required, government can play a huge role by supporting the construction industry with investment in the form of technology, resources and tools. Investment would also be required in the form of empowering people in the construction industry. Investment in these areas would help to lay a good foundation for the construction industry to be able to adopt and implement BIM.

#### **7.4.1.2 Construction Organizations**

In line with the adoption and implementation of BIM in the construction industry, construction organizations would be at the forefront of the process. This is because the construction industry would be the users and adopters of BIM. As part of their role, construction industry personnel would be required to make investments in the form of BIM technologies, tools and other resources. The construction industry would also be required to adopt new and modern ways of doing things through better collaboration and communication among all the parties in the industry. Better processes of design, procurement, and constructing buildings should be adopted. The construction industry also needs to present construction clients with the idea of BIM and its benefits for the industry. Doing this requires training and education of the people within the construction industry about the benefits of implementing BIM. Findings from the quantitative study (see section 5.3.1) show that there is little awareness of the benefits of adopting BIM and the benefits at different maturity levels. This training and education would prevent them from remaining stagnant at whatever level they are currently at. Some participants in the study did not know the difference between the various maturity levels, let alone the benefits. Having the required knowledge and knowhow would help the construction industry also to pass on this information to their clients. The industry would also be able to invest in training their personnel by organising BIM workshops and conferences, together with the assistance of educational and research institutions, to help improve the awareness of parties in the construction industry.

The construction industry is also seen as the agent of change in this regard. Implementing BIM requires changes in the ways in which the construction industry approaches construction processes, from design, through procurement, to construction and even management of constructed assets. The need for a cultural change in the construction industry will only be possible where construction organizations are willing and supportive of the changes needed.

#### **7.4.1.3 Educational Institutions**

Educational and research institutions will play a key role in the process of adopting and implementing BIM in the Saudi Arabian construction industry. The key roles of the educational institutions can be divided into two main areas: educating and training the construction industry in relation to the importance of BIM, the processes involved and best practices; and research into the performance of the construction industry and identification of bottlenecks or barriers to implementation.

As part of the foundation for adopting BIM in the Saudi Arabian construction industry, educational institutions can play a key role in improving the construction industry's awareness of BIM by organising educational workshops together with construction industry personnel on the importance of BIM as well as ways to implement and manage BIM projects. The educational institutions can also incorporate BIM subjects and relevant modules – such as construction procurement routes, use of CAD and other inter-operable software – into the training of students who will become professionals in the industry. The introduction of BIM into the curricula of construction-related courses will help to ensure graduates are prepared for a construction industry with a BIM focus. Education can also focus on best practices and alternative processes that can help support BIM implementation with an emphasis on the characteristics of the construction industry.

The second role of educational and research institutions will be to research into the performance of the construction industry by periodically developing research agenda for the industry. This will also involve research into barriers to the adoption and implementation of BIM. To ensure the educational institutions achieve this, investment will also be required from both government and the construction industry, who will support the educational and research institutions with the funds required to pursue such research.

As reported in the literature review, Arayici *et al.* (2011) observed that clients are placing increasing pressure on different professionals in the industry to adopt and implement BIM for their projects. Therefore, all the professions need to be trained and educated about the BIM tools and their application. Furthermore, findings from the quantitative study also showed that there is a lack of skilled BIM personnel in the Saudi construction industry (see section 5.3.2 and Chapter 3). Therefore, there is a need for training and for creating awareness of BIM.

## 7.5 GUIDELINES FOR IMPLEMENTING A NATIONAL BIM STRATEGY FOR THE SAUDI ARABIAN CONSTRUCTION INDUSTRY

To implement the framework for a construction industry-wide BIM adoption in Saudi Arabia as shown in Figure 7.2, nine key steps must be taken. Table 7.1 below details guidelines for ensuring that the implementation of the framework can lead to the required results.

**Table 7.1: Guidelines for Implementing a National Strategy for BIM Adoption in Saudi Arabia**

Key Steps For Implementation	Suggested Actions
<b>1. Develop BIM Task Group</b> <ul style="list-style-type: none"> <li>• Set National Agenda for BIM</li> <li>• Set goals to be achieved</li> <li>• Enact relevant legislation</li> </ul>	<p>Setting up a BIM Task Group which will have the mandate to set the national level agenda. As part of the agenda for BIM implementation, goals will need to be defined for the national implementation of BIM with timelines for when such goals or targets should be met. Subsequently, formulating a national agenda for construction industry-wide BIM implementation requires setting goals (targets) and time scales for achieving such targets. This requires having a system in place to monitor and measure such targets, and to make interventions when needed. The BIM Task Group will be in charge of the diverging swerving the goals in consultation with the construction industry and the educational institutions. Based on the outcome of this research, the national strategy will require legislative backing which can influence the larger industry. Just as government legislation has had an impact in other countries, it is expected that legislation will drive the change. The members of the BIM Task Group would be drawn from the industry, construction professional bodies, and academics from educational institutions, lawmakers and government representatives.</p>
<b>2. Set Foundation for BIM Adoption and Implementation</b> <ul style="list-style-type: none"> <li>• Framework development</li> <li>• Information-sharing</li> <li>• Collaboration</li> <li>• Processes</li> <li>• Common methods</li> </ul>	<p>The second step to a successful BIM implementation in the Saudi Construction industry will be the need to set the foundation for BIM adoption. Besides setting targets and enacting legislation, there is also a need to ensure a solid foundation to provide the basic requirements for BIM. The essence of the foundation is to ensure there is a change in the construction industry in terms of behaviours of people, and change in practices as well as processes. For the purposes of a national level BIM implementation, there should be a national framework which sets the common agenda. As part of the foundation, it is necessary to ensure that the construction industry is ready to adopt BIM. The foundation for BIM should ensure there are systems in place that support information-sharing, and promote collaboration, improved processes and common methods across the construction industry. Achieving this foundation requires a cultural change in the construction industry as well as investment in the industry.</p>

<p><b>3. Cultural Change</b></p> <ul style="list-style-type: none"> <li>• Practices</li> <li>• People</li> </ul>	<p>BIM implementation and adoption require change in terms of the practices of the construction industry and the attitudes of people within it. In this regard, change in practices should target design and procurement practices. The current practices within the Saudi construction industry will require change to ensure BIM implementation can be supported. Key areas that require change include the design and procurement of projects. As captured in countries where BIM implementation is advanced, changing the basis for forming construction contracts can help create the foundation for adoption. Collaborative procurement methods such as partnering and integrated project delivery will help BIM implementation.</p> <p>Another area for change is the behaviour of people within the construction industry, which can adopt BIM and benefit from it if the people (major players) have the right attitude, which includes an attitude of collaboration where people are willing to work together on projects, sharing information and collaborating with other professionals. The success of BIM relies to a large extent on the willingness of people to do this. Changing practices and people's attitudes require legislation and education. Change in attitudes towards collaborative working and change in style of communication can be achieved through education.</p>
<p><b>4. Education</b></p> <ul style="list-style-type: none"> <li>• Awareness</li> <li>• Benefits</li> </ul>	<p>The change required in the construction industry will (in terms of practices and attitudes) require education. Education for the purposes of BIM adoption and implementation should seek to ensure that all the stakeholders understand the need for change. Education should promote awareness of the construction industry players of practices that support BIM implementation as well as the benefits they will gain from this. This research has found that the current understanding of BIM is not very advanced, and some of the construction industry players and education can help to enhance this. Education should also seek to guide people on the need for collaboration and improved ways of communication within the construction industry.</p> <p>Education should be provided by the educational institutions to industry personnel and BIM should be included in the curriculum for training the construction professionals. Education for the purposes of BIM should also ensure that new professionals are trained and equipped with the knowledge and skills required for successfully implementing BIM by adopting new practices.</p>
<p><b>5. Investment by Government and Construction Companies in:</b></p> <ul style="list-style-type: none"> <li>• Technology</li> <li>• Tools</li> <li>• Resources</li> </ul>	<p>Creating a foundation for BIM adoption also requires investment. This investment is expected to improve the readiness of the construction industry in terms of required technologies, tools and resources that can help BIM implementation. Due to the level of investment required, construction industry-wide support is required, so as to enable and empower companies. Investment in technology refers to having the infrastructure in place to support BIM implementation as well as investment in the enabling tools which are required, such as BIM toolkits, costing tools and analytical tools. Investment in technology should also include</p>

	ensuring that people are trained to have the knowhow for using such technologies. Section 5.3.3 shows that there is very low usage or experience with BIM tools and their applications in the KSA construction industry, and this is also associated with the low awareness. Therefore, there is a need for significant training and awareness creation in relation to the BIM tools and technologies.
<b>6. Implementation of BIM</b>	Implementation of BIM on projects will work best once a good foundation has been established, common standards developed, and a construction industry-wide perspective developed. As in other countries' construction industries (such as in the UK where BIM is advanced), implementation on a construction industry scale will help lead to transformation. Implementation should focus on achieving the correctly defined targets and goals. BIM implementation in Saudi Arabia should also consider making BIM practice mandatory through government legislation (starting with government projects and potential take-up by all project types).
<b>7. Performance Measurement</b>	There is a need to have in place a system for measuring the performance of the construction industry in terms of BIM adoption and implementation. There should be a periodic measurement of the performance through strong practical research at least once every five years to determine how well the industry is responding to the adoption of BIM. This should concentrate on the changes brought about in the construction industry as a result of BIM adoption and implementation. A timescale for performance measurement should be designed based on the goals for the national strategy. This will help to identify any challenges with the strategy and identify methods for overcoming those challenges. The performance measurement system should also consider how well the adoption of BIM has impacted on the performance of projects in terms of project delivery time, cost, quality, minimizing and resolving disputes, and health and safety, among others.
<b>8. Identify and Address Challenges:</b> <ul style="list-style-type: none"> <li>Barriers to BIM adoption</li> </ul>	As identified from this research, a number of challenges are likely to occur due to the current nature and level of the Saudi Arabian construction industry. Barriers such as costs, lack of regulation, lack of manpower, fear of change, and team culture need to be overcome to ensure better performance. The barriers and challenges can be identified and addressed through research as part of the system for developing the foundation for BIM and through a periodic review of the BIM agenda.
<b>9. Review of National Strategy</b>	The final stage of the national strategy for implementing BIM in the construction industry of Saudi Arabia is a periodic review of the strategy based on the performance of the construction industry and the challenges or barriers faced. This helps to inform the strategy by setting more realistic time-lines and finding solutions to the problems. The review will be carried out at five years intervals by the BIM Task Group.

As has been shown in the implementation plan, BIM adoption in Saudi Arabia is possible if the correct measures are put in place. With reference to Jung and Joo (2011), the developed framework and its implementation should ensure that the construction industry as a whole benefits from the strategy, and these benefits can then trickle down to organizations and individual projects. The parties required for implementing the framework and their key roles have been presented in section 7.3 of this chapter. The framework will be owned by the government and implemented by the BIM Task Group set up by the government.

In implementing this strategy, there is a need to acknowledge that issues are likely to come up. There should therefore be an attempt to identify these issues with implementation ahead of time and to put in place measures to ensure that such issues are corrected using the appropriate approaches.

## **7.6 SUMMARY OF CHAPTER SEVEN**

As indicated in the introduction to this chapter, the chapter set out to develop a strategy for adopting and implementing BIM within the Saudi Arabian construction industry. The development of the framework has come about as a result of the research undertaken over a period of three years. This strategic framework therefore serves as a practical contribution by this research to the construction industry. In developing the framework, this research considered the results of the research as well as the published best practices from other countries where BIM adoption in the construction industry is more advanced. Moreover, the NBS periodic table for BIM implementation was reviewed and considered in developing the strategic framework and the implementation guide for ensuring the framework would meet its intended goals. The results captured from both the quantitative and qualitative data analysed for this research provided the basis for ensuring the strategy developed is fit for the KSA construction industry. This is because the data presented issues specific to KSA in terms of awareness, adoption and benefits, and the barriers to the implementation of BIM in the Saudi construction industry.

From the framework developed, it can be ascertained that BIM implementation within the Saudi construction industry requires a holistic approach, with efforts from the government as well as from all the stakeholders within the industry. The key requirements for BIM adoption according to the research are: establishing a solid foundation that enables both adoption and

implementation and which targets the transformation in the process and practices in the construction industry; education of the professionals in the construction industry on the need for collaboration and new means of communicating construction information; education of all stakeholders in the construction industry on the awareness and benefits of BIM; and a construction industry focus in terms of implementation. The implementation guide provided in this chapter is intended to serve as a means to help policy makers and parties (the Task Group) in charge of ensuring BIM adoption and implementation in the Saudi Arabian construction industry. From the guide and the framework developed, it is expected that BIM adoption in the Saudi construction industry can be successful, based on the right policies, and with the means to monitor progress and implement changes where necessary.

# **CHAPTER EIGHT**

## **RESEARCH VALIDATION**

### **8.1 INTRODUCTION TO CHAPTER EIGHT**

The previous chapter of the study presented the outcomes from the research findings together with an integrated framework to guide the implementation of building information modelling (BIM) in Saudi Arabia's construction industry to enhance the industry's performance. Nevertheless, the extent to which the findings of the research can be relied upon depends greatly on the validity of the processes that were used.

### **8.2 RESEARCH VALIDITY**

Research findings help to provide procedures which can be used to enhance the measures that already exist. However, it is of great importance to establish the validity of the findings, in order to ensure that the anticipated improvement of processes can be consistently achieved when the outcomes of the research are put into practice. Validation is seen as the method for evaluating the gradation by which a measure accurately represents what it justifies or is expected to quantify (Hair *et al.*, 2010). Nevertheless, the validation process is not limited to establishing the validity of the research findings but is also used for validating the research design (Brewer, 2000). From the above explanation of research validity, four aspects of validity need to be recognised for a validation process to be considered successful (Cook and Campbell, 1979; Shadish *et al.*, 2002). The aspects are: -

1. Validity of research constructs
2. Validity of statistical findings
3. External validity
4. Internal validity

The validity of the concepts and the statistical findings in this research study has been confirmed from the pilot study carried out and the inferential statistical techniques used have



also been discussed in the previous chapters. This chapter of the study therefore focuses on the external and internal validation aspects.

### **8.3 EXTERNAL VALIDATION**

The main purpose of external validation is to gain self-confidence in the research findings and what they represent. This helps to enhance the robustness of the research and also to generalise the findings regardless of the settings and research method used (Shadish *et al.*, 2002; Fellows and Liu, 2008; Bashir, 2013). External validation is further divided into: replication, convergence analysis and boundary search.

#### **8.3.1 Replication**

This involves re-examining a research process using the same procedures (experimental, conceptual and theories), instruments, research design and research strategy to obtain the same results (Rosenthal and Rosnow 1991). This process is also seen as a reliability test for the research (Kerlinger and Lee 2000). However, a number of constraints in terms of logistics are associated with repeating the research process involved with social research and it is also difficult to achieve an exact replication because two occasions can never be the same. Thus, in practice replication is hardly used (Brinberg and McGrath 1985; Ankrah 2007; Bashir, 2013). For this study, based on the logistical problems of repeating the survey, it was unrealistic to expect that the same particular respondents would be willing to complete the same survey again, considering the efforts it took in the first place to enable the respondents to see the reasons why their response was important to the outcome of the study and also the comprehensiveness of the survey instrument used. The survey instrument used was developed and piloted to certify that data collected from the study were reliable.

#### **8.3.2 Boundary Search**

Boundary search is also referred to as discriminant validity and helps to identify the limits/boundaries associated with a particular piece of research, according to Brinberg and McGrath (1985) and Rosenthal and Rosnow (1991), who were further of the opinion that it is usually rare to find a research study extending beyond replication and convergence analysis. For this research study, boundary search was not adopted, due to the constraints, mainly of time and cost, on achieving the aim of this research study. However, convergence analysis was adopted for this research study.

### **8.3.3 Convergence Analysis**

Convergence analysis comes into play when different research methodologies have been used to establish agreement from research findings. This type of analysis also helps in assessing the robustness of a piece of research (Ankrah 2007; Denzin 2009). In this research study, both quantitative and qualitative methods were used in order to discover significant agreement between the research findings.

Convergence validation can be achieved by a process called respondent validation, which usually involves the use of participants' opinions to authenticate the validity of the research outcome (Silverman 2006; Creswell 2009). The convergence analysis approach has been considered a feature of good research and has been adopted previously on construction management research (Hari *et al.*, 2005; Ankrah 2007; Anvuur, 2008; Tuuli 2009; Manu 2012). In the case of this research, it was possible to conduct a follow-up interview with the respondents, so as to authenticate the research findings (Phua 2004). This approach was therefore adopted in this study, using professionals in Saudi Arabia's construction industry. This structured interview contained questions that would help to authenticate the validity of the findings from the research and the significance of a developed framework for the country's construction industry.

Participants chosen for the convergence validation had partaken in both the quantitative and qualitative research conducted. They had indicated their interest in the findings of the research study and also in participating in subsequent stages of the research. A total of 10 professionals from the Saudi Arabia construction industry were therefore invited to take part in the validation process. Questions from the interview and framework were sent with the invitation and there was a follow-up via phone calls.

## **8.4 RESULTS OF RESPONDENT VALIDATION**

Interviews were conducted with 10 professionals practising in the Saudi Arabian construction industry. These professionals, as mentioned in Chapter 6, were: Infrastructure Development Engineer (R1), Educationist and Consultant in BIM (R2), Planning and Architectural Engineer (R3), Industrial Project and BIM Consultant (R4), Architectural Engineer (R5), Commercial Sector Development Engineer (R6), Educationist and Project Manager (R7), Mechanical Electrical Plumbing Engineer (R8), Real Estate Development Engineer (R9), Project Manager (R10), Project Manager at the Ministry of Education Works Department (R11). They operate both in the public and private sector of the construction industry in Saudi

Arabia, with more working in the private sector. This indicates the dominance of the private sector in the construction industry. The operating sector of the professionals practising in Saudi Arabia and their years of experience places them in the best position to give a first-hand opinion to be used for the validation of the research findings.

The feedback on the validity of the findings of the research framework as shown below indicates that the framework is valid due to the respondents. As regards understanding how the framework of the research should work, 3 of the respondents agreed that it was valid while the remaining 7 of the respondents strongly agreed that it was valid. The relevance of the framework to the construction industry in Saudi Arabia was also attested to by the respondents, 2 of whom averagely agreed that the relevance of the framework was valid, and 4 agreed it was valid, while the remaining 4 strongly agreed that it was valid. Judging from the validity of the relevance of the framework, 4 respondents strongly agreed on the validity of the framework and that it can be implemented in the Saudi Arabia construction industry, 4 respondents agreed that the framework is valid to be implemented while 1 of the respondents averagely agreed on the validity of the framework.

On the comprehensiveness of the framework in facilitating the implementation of BIM in the Saudi Arabian construction industry, 8 of the 10 respondents agreed that the framework was valid while the remaining 2 respondents strongly agreed that the framework was valid in facilitating the implementation of BIM.

With regards to the comprehensiveness of the framework, it was also validated by the respondents as contributing significantly to the smooth take-up of BIM in the Saudi Arabian construction industry. Out of the 10 respondents, 7 strongly agreed that the framework was valid while 3 respondents agreed that the framework was valid, for the smooth take-up of BIM in Saudi Arabia's construction industry. From Table 8.1 the output of the feedback from validation findings is shown in detail.

**Table 8.1: Feedback from Validation Findings**

	<b>1- Strongly Disagree</b>	<b>2- Disagree</b>	<b>3- Average</b>	<b>4- Agree</b>	<b>5- Strongly Agree</b>
1- I understand how the framework should work.	0	0	0	3	7
2- The framework is relevant to the Saudi Arabian construction industry.	0	0	2	4	4
3- The framework can be implemented in the Saudi construction industry.	0	0	1	5	4
4- The framework is very comprehensive in facilitating the implementation of BIM in the KSA.	0	0	0	8	2
5- Implementation of the framework will contribute significantly to the smooth take-up of BIM in the Saudi construction industry.	0	0	0	3	7

Respondents made some observations about the framework and suggested things to be done to improve its validity for the study. The observations of the respondents were:

*“There is no starting point for the framework”* [R1]

*“Action should be in one direction not two at some points”* [R2]

*“Change the arrow from educational institutions to construction companies to an influence arrow instead of an action arrow”* [R3]

*“There is a need to have a loop showing “end and restart”* [R4]

*“Use signs to indicate start, end and restarting points”* [R5]

*“The 4 large boxes should be in different colours from the colours used in the framework since they are only providing additional information for users”* [R6]

*“Use the keys to state what the different colours in the framework represent”* [R7]

*“Some arrow heads are missing; we need arrows that show the direction at all points”* [R8]

The suggestion made by R1 enabled the framework to have a starting point, that of R2 ensured that all actions in the framework would be in single directions and that of R3 has been reflected in the final framework developed for the study in Chapter 7. R4's suggestion of a loop has been created in the final framework, as has R5's suggestion, and all colours have been changed as suggested by R6. Information was added to show what each colour stands for in the key section, as suggested by R7, and all arrows are now placed and directions are clearly defined, as suggested by R8.

#### **8.4.1 Matters Which the Proposed Framework Fails to Take into Account**

Respondents raised some valid points on areas which the framework did not take into account:

*“Solid indicators to be measured by authorities and minimizing the period between measurements.” [R2]*

*“The government should implement BIM in mega projects then make recommendations about these projects and then make an Arabic standardization to implement BIM because using the Arabic language is easier.” [R3]*

*“I think we need to consider the evaluation of BIM technology and the free BIM applications.” [R4]*

*“Even though the study is about BIM in construction, it is good to clarify the importance and advantages of BIM to the owner and designer at a glance.” [R5]*

*“Clarify what the current situation of the Saudi construction sector is without the use of BIM.” [R6]*

*“The current [universities and training institutes] are not enough or suitable for the deployment of BIM training. You need a special, non-profit national centre for BIM.” [R7]*

#### **8.4.2 Feedback on Potential Benefits from The Framework Developed**

Validating a framework used for a study is of great importance to the study. It is also essential to find out the potential benefits of the framework to the industry where it will be applied. To achieve this, respondents were asked about the benefits of the framework to Saudi Arabia's construction industry. Out of the 10 respondents, 9 indicated that there were potential benefits, while one indicated otherwise.

*“It shows and simplifies the use of BIM in the KSA construction industry.” [R1]*

*“The success is shared between government, construction companies and educational institutes and touches in depth the Saudi environment.” [R2]*

*“Expand the BIM culture and it is good that the government is the leader to implement BIM because some people thought the government has limited possibilities.” [R3]*

*“Will set up a clear road for building industry to implement BIM.” [R4]*

*“Good clear strategy to apply BIM in Saudi construction sector.” [R5]*

*“BIM contributes to greater synergy between the components of the construction cycle (owner, designer and contractor).” [R6]*

*“BIM contributes to reducing cost and time in addition to improving safety in construction.” [R7]*

*“Availability of implementation if improved as follows.” [R9]*

*“Combine the public and private sector to use BIM and [see] how they collaborate.” [R10].*

## **8.5 SUMMARY OF CHAPTER EIGHT**

The chapter presented the process taken to validate the findings of the study through the use of external and internal methods of research validity. The external method of research validity was carried out via the convergence analysis approach, using respondents' validation. Interviews were conducted with 10 professionals in the Saudi Arabian construction industry to validate the findings of the research study and also assess the benefits and relevance of the proposed framework to the industry. The respondents were in agreement with the research findings and were of the opinion that the framework could help in the integration of BIM in the Saudi Arabia construction industry to enhance performance in construction projects. The respondents made some suggestions that were of help in improving the framework.

Internal validation of the study was established based on agreement between previous studies and the findings from the research study and also through academic validation drawn from the research publications and posters.

Having validated the findings of the research study, the sixth objective of the study which was to develop and validate strategies/a framework for adopting and implementing BIM in the Saudi Arabian construction industry has been addressed.

# **CHAPTER NINE**

## **FINDINGS, CONCLUSIONS AND RECOMMENDATIONS**

### **9.1 INTRODUCTION TO CHAPTER NINE**

This chapter presents the findings, conclusions and recommendations drawn from the entire research. It begins with a brief discussion on the rationale of the research, followed by a summary of how the key research aim and objectives were achieved in the study. Finally, recommendations to practitioners and policy makers are made.

### **9.2 RATIONALE OF THE RESEARCH**

The construction sector, which is a major industry player in the Kingdom of Saudi Arabia, is currently facing an unprecedented boom due to the country's move to develop the infrastructure and tourism industry, as a means of reducing its dependence on the oil sector. However, the Saudi Arabian construction industry was found to be slow in adopting new innovative technologies in comparison to other industrial sectors. As such, the industry is faced with inherent problems such as poor project management, design mistakes and discrepancies, delays in execution of work, design change orders, lack of collaboration among project participants and poor site management. In order to tackle these problems, innovative solutions need to be found.

Building Information Modelling (BIM) is an innovative technology considered globally to have a positive impact on the successful delivery of projects on time, within the stipulated budget and to the right specification. This is possible due to its in-built object-oriented, intelligent and parametric information system that shows a detailed and complete replication of a building in three dimensional (3D) formats, which permits all stakeholders in the built environment to team up more efficiently and accurately throughout the life cycle of a construction project. Consequently, higher profits, greater precision, better quality and a safer working environment have been achieved in developed nations due to the application of BIM. Unlike the developed world, in Saudi Arabia there is no empirical evidence that shows how BIM has been successfully applied in the country's construction industry. Furthermore, the limited studies conducted on BIM did not propose effective strategies that could facilitate the

adoption of BIM in this industry. It is against this background that this study employed both quantitative and qualitative research methods in order to evaluate the extent of BIM usage in the Kingdom of Saudi Arabia and identify the inherent barriers that affect its full usage. Based on the outcome from the study, a strategic framework was developed to serve as a guide for the adoption of BIM in the Saudi Arabian construction industry.

### **9.3 ACHIEVEMENT OF THE RESEARCH AIM AND OBJECTIVES**

This research has achieved its aim of studying the extent of the use of BIM in the Saudi Arabian construction industry and the barriers to its full adoption in the industry. This achievement is explained in detail in Chapters 3, 5 and 6 of this study. Furthermore, the research has produced a framework that could facilitate the smooth and successful adoption of BIM in the Kingdom of Saudi Arabia and Chapter 7 explained this framework.

In undertaking this study, the research problem has influenced the methodology adopted, the data collection techniques employed and the type of analysis suitable for achieving a reliable and valid result. These choices have facilitated the achievement of the objectives in this study. The research objectives are restated below, to highlight the extent to which they were achieved throughout the phases of the research.

#### **9.3.1 Objective Number One**

The first objective was **to identify the functionalities, implementation, advantages and disadvantages of BIM**. To satisfy this objective, an in-depth review of literature was conducted in Chapters 2 and 3 where the major functions or purpose, and the advantages and disadvantages of BIM, were clearly identified. From the reviewed literature, it was seen that the major drive behind the use of BIM in the construction industry is to improve interoperability and collaboration among the stakeholders in the construction industry so as to produce the best quality design while optimising cost and minimising the time of project delivery. BIM provides several advantages such as:

- How the contractor's requirements can be programmed and captured in early design phases
- How the design alternatives would affect the structure and embodied energy
- How engineers and professionals would collaborate during the project processes
- How the building will be constructed and operated after being handed over



BIM affects these processes and phases intelligently and further improves on those processes as it has the capability to check for design errors. Beyond its 3D properties, BIM presents added advantages, such as cost estimating, scheduling or programming, facility management related information, and sustainability. In other words, BIM has the advantage of incorporating all the intricacies involved in the three major phases of a project lifecycle: design, construction and management. This multi-functionality and advantages of BIM in tackling and improving all aspects of the construction industry has helped BIM to gain popularity in various developed countries such as the United States, United Kingdom and Germany. The rapid implementation of BIM in these countries has been attributed to a functioning governmental policy to increase productivity in construction, minimize construction waste resulting from design and management flaws, improve collaboration and communication among project stakeholders, and enhance technology and educational institutions through the promotion of innovative ideas. However, BIM also presents some barriers, such as the high cost of software, lack of experts, legal issues, and incompatibility with partners.

In developing countries, this new paradigm has only recently started to be implemented, with UAE, South Korea, Singapore and China at the forefront. However, there is lack of empirical data on BIM awareness and application in the Saudi Arabian construction industry. Against this backdrop, the present study adopted scientific approaches to investigate the awareness, application, benefits, barriers and the drivers that could facilitate the adoption of BIM in the Saudi Arabian construction industry.

### **9.3.2 Objective Number Two**

The second objective, which was **to study the awareness of BIM in the Saudi Arabian construction industry**, was satisfied through the quantitative and qualitative analyses of data obtained from the major stakeholders in the Saudi Arabian construction industries. The findings are summarized below:

#### **9.3.2.1 Findings from the Quantitative Study**

The use of mixed method of research is believed to be plausible in developing both quantifiable and comprehensive outcomes. Thus, this study considered the benefits mentioned and employed both methods. Chapter 5 presented the findings from the quantitative study conducted with experienced professionals who work in both private and public sector construction projects. This means that their opinions are important in obtaining

reliable answers to the questions on BIM in the Saudi Arabian construction sector. From the survey conducted using 224 respondents, 17% of the entire sample sizes were not aware of BIM, while over 80% indicated different levels of BIM awareness and usage. Nonetheless, the overall result indicated that the level of awareness and familiarity of BIM was quite low in the Saudi Arabian construction industry. This finding is in accordance with the literature published after the data collected for this research study, which clearly stated that BIM is in its immature stage in the Saudi Arabian construction industry but is emerging to some extent. This situation could be ameliorated by developing a framework that would help professionals in the built environment to enlighten and guide other construction stakeholders on the benefits of employing BIM to deliver projects.

In an attempt to obtain further information on the levels of BIM awareness across and within the different organizations sampled in this study, the research cross-tabulated four levels of BIM awareness within the different organizations surveyed. The results showed that majority of the respondents who are fairly familiar with the use of BIM are working with consultants and the contractor organizations. In terms of their specific roles, these respondents are mostly Project Managers, Civil Engineers, and Directors. This result also indicates that BIM awareness is very low in the Saudi Arabian construction industry and that therefore the training of personnel on the advantages of BIM and the processes involved in its adoption will be essential.

To further accentuate the results on the awareness of BIM within the KSA construction Industry, the study undertook a correlation test using the Kendall's correlation coefficient, and the test revealed a high correlation between the years of working experience, high qualifications, and age group with awareness of BIM in the Saudi Arabian construction industry, which means that the higher these variables were, the higher the level of awareness of BIM.

#### **9.3.2.2 Findings from the Qualitative Study on the Awareness of BIM**

Chapter 6 presented the findings from the qualitative study conducted using semi-structured interviews. These interviews were conducted among construction professionals operating on various projects in some selected organizations. These personnel are deeply involved in sharing information on projects in their respective organizations.

On average, the interviewees have some degree of awareness and understanding of the importance of BIM, although their level of understanding differs. For instance, although the

majority of the interviewees are aware of the benefits of BIM to construction, most have never had any training in its use. However, four of the interviewees have undertaken such training for the use of BIM processes, its technology and softwares, and are now using BIM to avoid construction problems and prevent delays in construction, while the least number of interviewees revealed that they have a low level of BIM awareness and understanding.

As the results from the qualitative and quantitative studies show, the majority of the stakeholders in the Saudi Arabian construction industry are aware of the importance of BIM but they do not fully understand its semantic or how it is used. This is the result of a lack of training and a poor educational system, as identified in both the literature and the results in this study. Thus, educational institutions could provide a means for improving awareness of BIM by organising educational workshops together with industry professionals on the benefits of BIM and effective ways to implement and manage BIM in construction projects. The educational institutions could also incorporate BIM subjects and relevant modules into the training of students so that they graduate prepared for a construction industry with a BIM focus. Investment in BIM research by both government and construction industry could also promote awareness of BIM and inform industry professionals and clients on the various barriers to the implementation of BIM.

### **9.3.3 Objective Number Three**

The third research objective was **to empirically investigate the use of BIM and the barriers to its use in the Saudi Arabian construction industry**. This objective has two parts: (1) the status of BIM usage in Saudi construction organisations and (2) the barriers to its use. These two parts are therefore discussed independently.

#### **9.3.3.1 The Usage of BIM in Saudi Construction Organisations**

This part of the objective was achieved through a quantitative method and subsequently presented in Chapter 5 of this study. The result showed that 26.4% of the respondents have never used BIM in their organizations, while 36.1% of the respondents use BIM frequently. Taking the overall result, 73.6% of the respondents have used BIM in one way or the other. From this result, it can be seen that there is a usage of BIM among the various organizations in the Saudi Arabian construction industry. According to the literature, the low adoption and usage of BIM is largely dependent on the low level of awareness of it. Therefore, promoting awareness of BIM and its benefits to construction industry will invariably lead to an increase in the level of BIM usage in the industry.

Collaboration and communication among the parties for its adoption will not only involves the technological aspects but also socio-cultural behaviour change in the construction industry. This means a change in the attitudes of the people involved (stakeholders) and the working practices in the construction industry. For the Saudi Arabian construction industry, the processes involved in sharing information, plan of work, and common data environment need to be improved to ensure a successful implementation of BIM. This could be made possible with government intervention and the creation of a BIM task group that would oversee the change in processes in the construction industry.

According to the responses from the interviewees, BIM presents a number of barriers, despite the benefits it brings to the industry. Nevertheless, this should not cause alarm, because greater benefits usually come from overcoming inherent challenges. The major barriers identified in the qualitative study are lack of knowledge, cost of implementation, and fear of change from traditional methods. Other barriers are legal and contractual issues, team culture, client awareness and requirements, and lack of strict government rules and regulations.

In the reviewed literature, the lack of knowledge and cost of implementation of BIM were identified to be the major barriers to BIM. Others were fear of change and the unwillingness to adopt an unfamiliar new technology.

The results from the qualitative study in Chapter 6 revealed that quite a few fears were demonstrated by the interviewees in the study. Although all the interviewees were aware of the benefits that BIM could bring to the construction industry, they still had some apprehension regarding the adoption of new technology. The first major fear identified by the respondents was the initial cost together with the running costs of BIM. One of the respondents explained that the application of BIM meant considerable expenditure on any project and therefore its application would be a threat to their organizations profit margin. However, they failed to consider the likely reduction in the whole life cycle cost of a construction project implemented using BIM.

#### **9.3.4 Objective Number Four**

Objective four aimed **to develop a framework and validate the strategies/framework for adopting and implementing BIM in the Saudi Arabian construction industry**. In developing the framework for its adoption in the industry, this study considered the results captured from both the quantitative and qualitative data analysed as well as published best practices from other countries where BIM has been successfully employed. Taking into

consideration the outcome of both qualitative and quantitative research, it was evident that BIM implementation in the Saudi Arabian construction industry required a strategic approach with an emphasis on collaboration between the parties, developing and training of personnel, and investment in the appropriate resources and tools. The results on the current reasons for BIM adoption, the barriers for implementation, and views on the benefits of BIM, as presented in the qualitative and quantitative results, implied that the framework for BIM implementation should be able to cover all the key areas identified in the outcome of the study. In line with the results, the National Building Specification periodic table for BIM implementation was reviewed and adopted in developing the strategic framework. However, in this case, the strategy considered issues particular to the Saudi Arabian construction industry, such as awareness, adoption, benefits and the barriers to the implementation of BIM in the country's construction industry. The framework developed revolves around three core groups, identified as the government, the construction industry and educational institutions.

The role of the government in the framework covers three main areas: setting up a national agenda for BIM, developing a BIM task group and investing in BIM for the benefit of the construction industry. Thus, to ensure a good foundation for the national adoption of BIM, the government needs to set up mandatory requirements for implementing BIM in publicly owned projects. This will help standardize practices within the construction industry and push construction companies and other parties to adhere to the required standards and embrace BIM. The major purpose of the task group in the framework is to ensure that a clear pathway is developed with an agenda and timelines to be monitored in order to achieve key milestones. Furthermore, the task group is responsible for measuring the Key Performance Index of the construction industry in terms of BIM implementation, and also reviewing the agenda every five years to address any challenges that have the potential to cause obstruction in meeting targets. In order to encourage the application of BIM, the government needs to support the construction industry with investment in technology, resources and BIM tools for the empowerment of personnel working in the Saudi Arabian construction industry.

The role of the construction industry in the framework is to ensure that industry personnel invest in BIM technology, tools and other resources. The construction industry also needs to adopt new and modern ways of doing things through increased collaboration and communication among all the parties in the industry, improved processes of design and procurement, and enhanced ways of constructing buildings. The construction industry also needs to introduce construction clients and professionals to the idea of BIM and its benefits

for the industry. This requires investing in the training and education of people within the construction industry through organising BIM workshops and conferences to promote awareness and motivate cultural change in the industry.

Finally, the role of the educational institutions in the framework is categorised into two main areas: (1) educating and training the construction industry in relation to the importance of BIM, the processes involved and best practices; and (2) promoting research into the performance of the construction industry and the identification of bottlenecks or barriers to BIM implementation. It is the role of the educational institutions to incorporate BIM subjects and relevant modules such as procurement routes, use of computer aided design and other inter-operable software, so that graduates become prepared for a construction industry with a BIM focus.

These three core groups will greatly influence the key areas of BIM implementation in the developed framework. These key areas serve as a means to help policy makers, stakeholders and the BIM task group in achieving a smooth and successful BIM implementation in the Saudi Arabian construction industry. From the framework developed, it is expected that BIM adoption in this industry can start when the right policies are instituted and monitored against a key performance indicator (KPI). To ensure that the expected improvements are achieved when the strategic framework are put into real practice, this study conducted a research validation.

The entire research findings were validated in Chapter 8 of this study, using both external and internal validation processes. The external validation process was carried out via the convergence analysis approach, using the respondents' validation. This involved obtaining participants' opinions on the validity of the research outcome as well as evaluating the relevance of the framework in the construction industry. Interviews were conducted with 10 professionals practising in the Saudi Arabian construction industry. Generally, the respondents were in agreement with the research findings and were of the opinion that the framework could help in the integration of BIM in the Saudi Arabian construction industry to enhance performance on construction projects. Thus, the feedback indicated that the framework was valid. However, the respondents made some observations about the framework and suggested improvements that would make the framework more valid for the study. Some of the points raised were the areas the framework did not consider, such as solid indicators to be measured by authorities, implementing BIM in mega projects by the

government to serve as an example, making Arabic the language required for implementation BIM, and creating a non-profit-making national centre for BIM training.

### **9.3.5 Objective Number Five**

This objective was **to draw conclusions and make recommendations to the Saudi construction industry regarding the future use of BIM in order to achieve better construction outcomes.** To satisfy this objective the conclusions to the research and recommendations based on the findings of the research are discussed in detail in this chapter.

## **9.4 OVERALL CONCLUSIONS**

In context, the construction industry is a key player in the economic growth of Saudi Arabia; in fact, its share in the economic dynamism of the Kingdom of Saudi Arabia is expected to rise because of the country's recent aim to develop its infrastructure and tourism industry. However, this intention could be a mere mirage, as the Saudi Arabian construction industry is slow in adopting new innovative technologies and is therefore faced, as mentioned, with inherent problems such as poor project management, design mistakes and discrepancies, delays in execution of work, and a lack of collaboration among project participants. The present study proposed tackling these problems through the adoption of Building Information Modelling (BIM).

BIM is an innovative technology that permits all stakeholders in the built environment to team up more efficiently and accurately in order to deliver projects to the right specification, whilst within the stipulated budget as well as being on time. Consequently, BIM has been applied in several countries around the world with significant benefits recorded. However, there is no empirical evidence to show its successful full implementation in the Saudi Arabian construction industry. It is against this background that this study bridged the already-mentioned research gap by employing the use of quantitative and qualitative research methods in developing a framework for the successful implementation of BIM.

A critical and in-depth literature review was carried out to distinguish the functionalities of BIM in the construction industry. The result among others revealed that BIM improves interoperability and collaboration among stakeholders in the construction industry and therefore produces best quality design, enhances cost reduction and minimizes the time of project delivery. Furthermore, it goes beyond three dimensional (3D) properties to produce cost estimates, a program of work, and facility management related information, as well as incorporating sustainability functions. This result clearly shows the potential advantage of

BIM in the construction industry. Unfortunately, the level of awareness of and familiarity with BIM in the Saudi Arabian construction industry was revealed through the quantitative analysis to be quite low though gradually emerging. This situation could be improved through the development of a strategic framework or guidelines that incorporate awareness programs or procedures that call for a complete change of attitudes and a mind-shift from poor traditional practices that yield less value, towards an innovative practice like the BIM integrated project delivery approach.

#### **9.4.1 Use of BIM**

On the issue of implementation, the quantitative analysis in this study discovered there is already usage of BIM in the Saudi Arabian construction industry. This result is consistent with the literature, which had revealed that nearly 25% of construction projects in the Middle East employ the BIM technology. However, it is imperative to mention that not all construction organizations in the Middle Eastern region who claim to use BIM employ it as an integrated tool for construction projects, and therefore these categories of organization do not benefit from the full capacity that BIM offers.

#### **9.4.2 Awareness of BIM**

As mentioned, the result from this study revealed the awareness of BIM among professionals in the Saudi Arabian construction industry to be quite low but gradually emerging. Through an in-depth investigation, it was revealed that the majority of those who are aware of BIM are top-rank stakeholders (that is, project managers, civil engineers and company directors) who have the potential to disseminate what BIM really entails. Thus, it was suggested that training personnel on the advantages of BIM and the processes involved in BIM implementation will be essential.

#### **9.4.3 Drivers of BIM Implementation**

The result of the study showed that the majority of construction organizations who use BIM do so because of its perceived benefits (cost savings, efficiency, quality and increase in productivity) and also to meet clients' expectations and requirements. Therefore, these drivers could be exploited when presenting construction stakeholders with the advantages of implementing BIM.

#### **9.4.4 Barriers to BIM Implementation**

In line with the objective of identifying the barriers of BIM usage in the Saudi Arabian construction industry, the respondents through a qualitative study identified the major barriers



to be lack of knowledge of BIM, initial and running cost of BIM implementation and fear of change from traditional methods. Furthermore, the fear of change from traditional methods was also observed and the respondents equally identified the major barriers as cost of implementation of BIM, lack of knowledge, and the training of personnel. The interviewees in the study were confident that if these top three barriers could be eradicated, BIM would be adopted easily in the Saudi Arabian construction industry.

#### **9.4.5 Strategies for BIM Implementation**

On the strategies that would facilitate BIM adoption in the Saudi Arabian construction industry; the first strategy identified was that the government should be the main anchor in the creation and enforcement of new rules and standards for BIM adoption in the industry. The second was the creation of a BIM task group and collaboration with BIM experts who would assist the Government in putting BIM adoption on the right track. The final strategy would entail increasing the level of awareness and knowledge of BIM through conducting conferences, seminars, workshops and training sessions and introducing BIM into the curriculum of educational institutions.

#### **9.4.6 Response to the Conclusions**

The strategies suggested above are intended as important recipes for an effective and successful adoption of BIM in the Saudi Arabian construction industry. However, the implementation of BIM will obviously need strategic guidelines to obtain the required outcome. It is therefore against this need that this study developed a strategic framework which would serve as a roadmap for the implementation of these strategies in the Saudi Arabian construction industry. The strategic framework was designed by considering the results captured from the analysis of the quantitative and qualitative data in this study as well as published best practices from other countries where BIM has been successfully employed. In line with this statement, the strategic framework was richly designed, by equally considering the particular issues in the Saudi Arabian construction industry. Accordingly, the framework is expected to guide the successful adoption of BIM in the Saudi Arabian construction industry under government leadership and support, with a flexible means to monitor progress, measure performance against set targets, identify and address challenges through periodic review of the BIM agenda and finally implement the necessary changes.

## **9.5 RECOMMENDATIONS TO PRACTITIONERS AND POLICY MAKERS**

Having considered the findings and conclusions from this research, the following recommendations are suggested:

- Educational institutions and construction organizations should periodically create awareness events through, for instance, workshops, seminars and conferences on the various benefits, barriers and counter-barriers of BIM practice, so that all the interested parties become deeply aware of what they are opting into.
- There should be a collaborative effort between the government, educational institutions and the construction sector to provide training on BIM through short courses and certified qualifications, and also to incorporate BIM into the academic curriculum in the universities and colleges with teach courses in architecture and engineering. In addition, BIM training and education curricula should be continuously updated based on international best practices to drive innovation, behavioural and cultural change.
- The government should establish policies that mandate the use of BIM as a key requirement for awarding and executing its minor and major projects.
- A task group comprising major industry professionals and policy-makers should be created to oversee the government intervention and change in process of BIM. Among the duties of the task group should be that of developing a clear pathway and agenda for implementing BIM, and to measure the Key Performance Index of BIM implementation and set targets.
- The construction industry should advocate a complete mind-shift from traditional practices that yield little value towards a more innovative and sustainable approach such as BIM.
- The construction and consultancy organizations should be required to make investments in the form of BIM technologies, tools and other resources that could promote or facilitate the implementation of BIM.
- In implementing the strategic framework proposed in this study, there is a need to acknowledge that issues are likely to come up. Therefore, a careful attempt to identify these issues ahead of time and put in place measures to address them at appropriate times should be considered.

## **9.6 RECOMMENDATIONS FOR FUTURE RESEARCH**

- Deeper research should be undertaken on the barriers in order to stipulate a much more detailed and extensive range of strategies which can be exploited to address these.
- Additional research should be carried out at wider level to focus on creating a BIM framework for the full adoption of BIM that can be applicable to the construction industry globally to reap the full benefits of its implementation.
- Further research should be taken to study the performance and effectiveness of BIM utilisation within the Saudi Arabian construction industry in order to measure the actual benefits of innovative BIM processes and technology.
- Future research can be conducted on the client's use of BIM. The investigation can be carried out to draw a clearer picture so as to enhance the understanding of the client's knowledge regarding BIM usage within the Saudi Arabian construction industry.
- A wide range of future studies can be conducted, based on the integral parts of BIM such as the use of BIM in the construction industry to improve safety during construction projects in Saudi Arabia.

## **9.7 CONTRIBUTIONS TO KNOWLEDGE**

This research has provided an insight into BIM adoption and implementation in the Saudi Arabian construction industry by investigating the current factors leading to the aspect of adoption. As part of the process, the research has made contributions to knowledge on the subject, most importantly in the Saudi Arabian construction industry. Although previous research had presented information on BIM implementation in the construction industries in other countries, this research has contributed by showing the factors specific to Saudi Arabia that impact BIM implementation, and this provides the knowledge for improving the adoption and implementation of BIM in Saudi Arabia and also other areas within the Arabian Gulf region. It is believed that the framework for BIM adoption developed by this research forms a good basis for deepening the current body of knowledge on BIM adoption and implementation in Saudi Arabia and elsewhere within the Arabian Gulf region. The implementation guide also serves as a source of knowledge for practice and for research as it can form the basis for more BIM related research specific to Saudi Arabia and/or the Arabian Gulf region. By reviewing and capturing data on the existing level of awareness in Saudi Arabia, this research provides the knowledge required for understanding the current level of awareness and taking the necessary steps to improve this level. This study has revealed the

existing level of BIM awareness and adoption in the Saudi Arabian construction industry in Chapters 5 and 6. Thus, the result could serve as a baseline for researchers and industry professionals to introduce strategies to improve the current situation.

- The barriers and counter-barriers of adopting BIM in KSA are identified in this study (in Chapters 5 and 6) could help prepare the mindset of interested parties opting for BIM implementation. Chapters 2 and 3 support this finding
- This study establishes scientific facts that provide a greater understanding of BIM and its numerous benefits which have the potential to improve the successful delivery of projects whilst maintaining quality, within the approved budget, and on time.
- The best practice framework for BIM implementation produced by this research serves as a basis for improving BIM implementation in the Saudi construction industry by providing information about the most important factors that need attention in the process. The step by step implementation guide provided by this research serves as a source of knowledge for new research which can help in improving the applicability and adoptability of the framework.

## **9.8 SUMMARY OF CHAPTER NINE**

Chapter 9 presented how the objectives in this study were achieved, the summary of findings, overall conclusions, recommendations and contributions to knowledge drawn from the entire research. Each of the objectives in the study was restated while reporting in detail the method(s) employed to achieve it, the results obtained and some validation of the results from the literature. The report was then briefly presented under the overall conclusion section to put forward all the research findings in a summarized form. To conclude the chapter, some recommendations and contributions to knowledge were also presented.

## REFERENCES

- Al-Ahli, S.A. (2004) *Saudi Economic Perspectives*. NCB Perspectives.
- Al-Ajlan, S., Al-Ibrahim, A. and Al-Ghamdi, F. (2006) Developing sustainable energy policies for electrical energy conservation in Saudi Arabia. *Energy Policy*, **34** (13) 1556-1565.
- Al-Abidien, Z.HM (1983) About the effect of delay penalty on the construction of projects and modification proposal. *Proceedings of the First Engineering Conference, King Abdulaziz University, Jeddah, Saudi Arabia*.
- Al-Barrak, A. (2004) *Causes of Contractors' Failures in Saudi Arabia*. Aldammam, Saudi Arabia.
- Al-Bogamy, A., Scott, D., Dawood, N., and Bekr, G. (2012) Addressing crucial risk factors in the Middle East construction industries: a comparative study of Saudi Arabia and Jordan. *Sustainable Building Conference, Coventry University*.
- Al-Bogamy, A., Scott, D., and Dawood, N. (2012). Addressing Construction Delays in the Kingdom of Saudi Arabia. *International Proceedings*.
- Al-Gahtany, M., Al-Hammadi, Y., and Kashiwagi, D. (2016), Introducing a New Risk Management Model to the Saudi Arabian Construction Industry. *Procedia Engineering*, 145, 940-947
- Al-Hammad, A.M. (1995) Interface problems between owners and maintenance contractors in Saudi Arabia. *Journal of Performance of Constructed Facilities*, **9** (3) 194-205.
- Al-Hammadi, S., (2015), An investigation into current tendering process in Saudi construction projects. *Proceedings of The Canadian Society for Civil Engineering 5th International/11th Construction Specialty Conference, University of British Columbia, Vancouver, Canada*.
- Al-Hammadi, S. and Nawab, M.S. (2016) Project Time Overruns in Saudi Arabian Construction Industry. *International Journal of Scientific and Engineering Research*, **7** (2) 555-560.
- Al-Husban, A. (2012) *What does the architectural creative leap look like through a conceptual design phase in the undergraduate architectural studio?* Unpublished Ph.D. Thesis. Washington State University, Pullman, Washington , USA.
- Al-Jarosha, Y. (2010) Expert warns of waste of 93 billion riyals in government projects in the coming years. *Alriyadh Newspaper*, Riyadh, Saudi Arabia. Issue 15409.
- Al-Jarboua, Z. (2009) The National Energy Strategy for Saudi Arabia. *World Academy of Science, Engineering and Technology*, **57** (3) 472-481.
- Al-Jibouri, S.H.S. and Ogink, G. (2009) Proposed model for integrating RAMS method in the design process in construction, *Architectural Engineering and Design Management*, **5** (4) 179-192.
- Al-Kharashi, A. and Skitmore, M. (2009) Causes of delays in the Saudi Arabian public sector construction projects. *Construction Management and Economics*, **27** (1) 3-23.

- Al-Khalil, M.I. and Al-Ghafly, M.A. (1999) Important causes of delay in public utility projects in Saudi Arabia, *Construction Management and Economics*, 17, 647 – 655.
- Al-Maatouk Q, Othman MSB, Al-khazraji A (2017) *A review on the potential of cloud-based collaboration in construction industry*. In: 2016 3rd MEC International Conference on Big Data and Smart City (ICBDSC), 1-5.
- Al-Mohawis, S., Assaf, S. and Khalil, M. (2005) *An Exploratory Study of Factors Impacting the Construction Industry in Saudi Arabia as a Result of Joining the WTO – Final Report*. King Fahad University of Petroleum and Minerals, Dhahran, Saudi Arabia.
- Al-Mohannadi, F. A., Arif, M., Aziz, Z. and Richardson, P. A. (2013) Adopting BIM Standards for Managing Vision 2030 Infrastructure Development in Qatar, *International Journal of 3-D Information Modelling*, 2 (3) 64-73.
- Almuntaser, T., Sanni-Anibire, M.O., Hassanain, M.A., (2018) Adoption and implementation of BIM – case study of a Saudi Arabian AEC firm. *International Journal of Managing Projects in Business*, 11 (3) 608-624
- Al-Mutiri, Y. (2016) *Empirical Investigation into Development of a Curricular Framework to Embed Building Information Modelling with Undergraduate Architectural Programmes within Saudi Arabia*. PhD Thesis, School of the Built Environment, University of Salford, Manchester, UK.
- Al-Najem, M., Dhakal, H. and Bennett, N. (2012) The role of culture and leadership in lean transformation: a review and assessment mode, *International Journal of Lean Thinking*, 3(1), pp. 119–138.
- Alnaser, A. and Harty, C. (2016) *The implications of BIM execution on communication channels in the design process*. In: CIB World Building Congress, Tampere, Finland.
- Al-Otaibi, M. and Price, A. D. (2009) Analysis and evaluation of criteria for pre-selecting contractors in the Saudi Arabian construction sector. In: Egbu, C. (ed.) *Proceedings of the 26th Annual ARCOM Conference*, 6-8 September 2010, Leeds, UK. Association of Researchers in Construction Management.
- Al-Otaibi M., (2011), Evaluation of contractor performance for pre-selection in the Kingdom of Saudi Arabia. PhD Thesis, Loughborough University, United Kingdom.
- Al-Otaibi, F., Yusoff, R. Z. and Islam, R. (2013) Total Quality Management Practices, Quality Culture and Competitiveness of Saudi Arabia Contractors, *Journal of Applied Sciences Research*, 9 (4), 2489-2497
- Al-Rashed, F. and Asif, M. (2014) Trends in Residential Energy Consumption in Saudi Arabia with Particular Reference to the Eastern Province, *Journal of Sustainable Development of Energy, Water and Environmental Systems*, 2 (4) 376-387.
- Al-Rashed, A., Taj, S., Phillips, M. and Kantamaneni, K. (2014), ‘Risk Assessment for Construction Projects in Saudi Arabia’, *Research Journal of Management Sciences*, 3 (7), 1-6
- Alreshidi, E., Mourshed, M., and Rezgui, Y. (2017) Factors for effective BIM governance. *Journal of Building Engineering*, 10, 89-101.
- Alsafouri, S., and Ayer, S. K. (2018) Review of ICT Implementations for Facilitating Information Flow between Virtual Models and Construction Project Sites. *Automation in Construction*, 86, 176-189.

- Al-Saudi, I.S.A. (2011) *The Impediments to the Adoption of the Design and Build Project Procurement Strategy in the Saudi Construction Industry*. PhD Thesis, Heriot-Watt University, Edinburgh, UK.
- Al-Sahli, A. (2011) *A Framework for Successful Implementation of IT for Construction Organizations in Saudi Arabia*. PhD Thesis, University of Salford, Manchester, UK.
- Al-Shaikh, S. A. and Chahine, P. (2010) *Saudi Construction Sector Review*. The Economics Department Research Team, NCB, Jeddah, Saudi Arabia.
- Al-Shammari, S.A. (2009) *Saudization and Skill Formation for Employment in the Private Sector*. PhD Thesis, University of Stirling, Stirling, UK.
- Al-Sapan, A. Al-Ghamdi, A. and Kabli, W. (2012) Project approval mechanism. Alriyadh Newspaper. [Online]. Available at <http://www.alriyadh.com/2012/09/18/article769208.html>. [Accessed 7 Jan. 2016].
- Alshawhi. M., Faraj, I. (2012) Integrated construction environments: technology and implementation. *Construction Innovation*, 2, 33–51
- Al-Shawi, M., Goulding, J., Khosrowshahi, F., Lou, E. and Underwood, J. (2009) How strategic is IT investment in the construction industry?, A UK Perspective, Modern Built Environment –Knowledge Transfer Networks, *Intelligent Buildings Index*, pp. 1-3.
- Al-Sayed, K., Dalton, R. and Hölscher, C. (2010) Discursive design thinking: The role of explicit knowledge in creative architectural design reasoning. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, **24** (2) 211.
- Al-Sedairy, S. T. (2001), A change management model for Saudi construction industry. *International Journal of Project Management*, 19, 161-169.
- Al-Sehaimi, AO, Tzortzopoulos, P and Koskela, LJ (2009), *Last planner system: Experiences from pilot implementation in the Middle East*, in: 17th Annual Conference of the International Group for Lean Construction, National Pingtung University of Science and Technology, LCI-Taiwan and LCI-Asia, Taipei, Taiwan
- Al-Shehri, M., Drew, S., Al-Hussain, T. and Al-Ghamdi, R. (2012) *The Effects of Website Quality on Adoption of E-Government Service: An Empirical Study Applying UTAUT Model Using SEM*. 23rd Australasian Conference on Information Systems, Geelong, Australia.
- Al-Sobieh, O.S., Arditi, D. and Polat, G. (2005) Predicting the Risk of Contractor Default in Saudi Arabia Utilizing Neural Network (ANN) and Generic Algorithm (GA) Technique. *Construction Management and Economics*, **23** (4) 423-430.
- Al-suliman, J., Graeme, B., and Chen, Z. (2012) *Current practice of variation order management in the Saudi construction industry*. 28th Annual ARCOM Conference Edinburgh.
- Al-Sultan, A.S. (1987) *Determination of Construction Contract Duration for Public Projects in the Kingdom of Saudi Arabia*. Masters Thesis, King Fahad University of Petroleum and Minerals, Dhahran, Saudi Arabia.
- Al-Sultan, K. S. and Al-Zaharnah, I.T. (2009) *Academia-Industry Innovation Linkages in the Case of Saudi Arabia: Developing a University-Industry Triple-Helix Framework to Promote Research and Development Collaboration*. PhD Thesis. King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Al-Sultan, F (2001) *Re-engineering Workflow: Theory and Applications* 1<sup>st</sup> edn Riyadh Al-Khalid Press

Al-Surf, M. and Susilawati, C. (2011) *Challenges Facing Sustainable Housing in Saudi Arabia: A current study showing the level of public awareness*. 17th Pacific Rim Real Estate Society Conference. Gold Coast, Australia.

Al-Thabt, A.A. (2013) *The Role Of Regional Development Policies In Local Economic Development*. PhD Thesis School of Architecture, Planning and Landscape Newcastle University.

Al-Thynian, F. (2010) An economic study reveals the reasons for the delay in the implementation of 82% of infrastructure projects in the Kingdom. *Alriyadh Newspaper*. Riyadh, Saudi Arabia.

Al-Tolany, S. (2013). Contractors are demanding the development of government procurement and contracting systems. [Online]. Available at <http://www.alyaum.com/article/3100418> Accessed 31 Jan. 2016].

Al-Tunisi, N. (2007) *Energy*. NCUSAR Publications - National Council on US-Arab Relations.

Alzara, M. Kashiwagi, J. Kashiwagi, D. and Al-Tassan, A.R., (2016) Using PIPS to Minimize Causes of Delay in Saudi Arabian Construction Projects: University Case Study. *Procedia Engineering*.145, 932-939

Abanda, F.H. and Byers, L. (2016) An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling). *Energy*, **97**, C, 517-527.

Abedi, M., Fathi, M. S., Rawai, N. M. (2014). The Impact of Cloud Computing Technology to Precast Supply Chain Management. *Int. J. of Constr. Eng. and Mgt.*, **2** (4), 13-16.

Abdulaal, W.A. (2011) Large urban developments as the new driver for land development in Jeddah. *Habitat International*, **30**, 1-11.

Abdulai, T. R. (2007) *The operation of urban traditional landholding institutions in sub-Saharan Africa: a Ghana study*. PhD Thesis, School of Engineering and the Built Environment, University of Wolverhampton, UK.

Abdulkadir A. G. and Godfauard A.J. (2017) BIM and project planning integration for on-site safety induction. *Journal of Engineering, Design and Technology*, **15** (3) 341-354.

Abubakar, M., Ibrahim, Y.M., Kado, D. and Bala, K. (2014) Contractors' perception of the factors affecting Building Information Modelling (BIM) adoption in the Nigerian construction industry. *2014 International Conference on Computing in Civil and Building Engineering*. Reston, USA: ACSE Library. pp. 167-178.

Abdul-Hadi, N. Al-Sudairi, AS. Alqahtani, S. (2005) Prioritizing barriers to successful business process re-engineering (BPR) efforts in Saudi Arabian construction industry, *Construction Management and Economics*, 23:3, 305-315,

Abdulhadi, N. (1997) *Simulation as a Tool for Re-engineering Construction Processes*, PhD thesis, University of Colorado



Ahmed, S.M. Emam, H.H. Farrell, P. (2014) *Barriers to BIM/4D implementation in Qatar*. In: The 1st International Conference of CIB Middle East & North Africa Conference, pp. 533–547, Abu Dhabi,

Ahuja, V., Yang, J. and Shankar, R. (2010) Perceptions affecting ICT adoption for building project management, *International Journal of Construction Management*, **10** (1) 94-110.

Akcamete, A., Akinci, B. and Garrett, J.H. (2010) Potential utilization of building information models for planning maintenance activities. *Proceedings of the International Conference on Computing in Civil and Building Engineering*, Nottingham, UK: Nottingham University Press.

AGC (2006) *The Contractors' Guide to BIM*. 1st edn. USA: Associated General Contractors of America.

AIA (2007) *Integrated project delivery: A guide*. 1st edn. California, USA: The American Institute of Architects (AIA) California Council.

Alazmeh, N, Underwood, J and Coates, SP (2017) Implementing a BIM collaborative workflow in the UK construction market. *Int. J. Sus. Dev. Plann.* **13** (1) 24–35

Ali, H. and Al-Falah, G. (2010) Sustainable Architectural Applications in the Gulf States – Post Occupancy Evaluation Case Study of Kingdom of Saudi Arabia. *Energy Systems Laboratory*. [Online]. Available at: <http://oaktrust.library.tamu.edu/handle/1969.1/93215> [Accessed 7 Jan. 2018].

Ali, H.M., Al-Sulaihi, I.A., Al-Gahtani, K.S. (2013) Indicators for measuring performance of building construction companies in Kingdom of Saudi Arabia. *Journal of King Saud University - Engineering Sciences*, **25**(2), 125-134

Alofi, A., Kashiwagi, J. and Kashiwagi, D. (2016) The Perception of the Government and Private Sectors on the Procurement System Delivery Method in Saudi Arabia. *Procedia Engineering*, **145**, 1394-1401

Alenazi, E. and Adamu, Z.A., (2017) Building information modelling for construction delay management. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, **11** (6), pp. 802-813.

Amjad, A.A. (1998) *Construction Procedure in accordance with ISO-9000 standards and FIDIC contract in Saudi Construction Projects*. MSc Thesis, Department of Building engineering and Surveying, Heriot Watt University, Edinburgh, UK.

Amos, T. and Pearse, N. (2008) Pragmatic research design: an illustration of the use of the Delphi technique. *Electronic Journal of Business Research Methods*, **6** (2) 95-102.

Andre, G. R. (2011) *Building Information Modelling (BIM): Special Contract Issues*. [Online] Available at: <http://www.klconstructionlawblog.com/2011/10/articles/articles-and-publications/buildinginformation-modeling-bim-special-contract-issues/> [Accessed 9 June 2016].

Ankrah, N.A., (2007), *An investigation into the impact of culture on construction project performance*. PhD Thesis, University of Wolverhampton, United Kingdom.

- Anumba, C.J. and Pulsifer, D. (2010) Knowledge management systems for construction. *Construction Research Congress, ASCE*, 687-696.
- Anvuur, A.M. and Kumaraswamy, M.M. (2008) *Better collaboration through cooperation*. In: Smyth, H. and Pryke, S. (Eds.), *Collaborative relationships in construction: developing frameworks and networks*. Oxford: Wiley-Blackwell.
- Arain, F.M. (2002) *Design-Construction Interface Dissonances*. unpublished MS Thesis, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.
- Aranda-Mena, G., John, C., Chevez, A. and Froese, T. (2009) Building information modelling demystified: Does it make business sense to adopt BIM? *International Journal of Managing Projects*, **2** (3) 419-433.
- Arayici, Y. and Aouad, G. (2010) Building information modelling (BIM) for construction lifecycle management. In: *Construction and Building: Design, Materials, and Techniques*. New York: Nova Science Publishers.
- Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K. (2011) BIM adoption and implementation for architectural practices. *Structural Survey*, **29** (1) 7-25.
- Arayici, Y., Egbu, C. and Coates, P. (2012) Building information modelling (BIM) implementation and remote construction projects: issues, challenges, and critiques. *Journal of Information Technology in Construction*, **17**, 75-92.
- Arbnor, I. and Bjerke, B. (2009) *Methodology for Creating Business Knowledge*. 3rd edn. London: Sage Publications Ltd.
- Argyrous, G. (2011) *Statistics for research: with a guide to SPSS*. 3rd edn. London: Sage Publications Ltd.
- Aronson, J. (1994) A Pragmatic View of Thematic Analysis. *The Qualitative Report*, **2**, 1-3.
- Assaf, S.A., Al-Khalil, M. and Al-Hazmi, M. (1995) Causes of Delay in Large Building Construction Projects; *Journal of Project Management in Engineering ASCE*, **2**, 45-50
- Assaf, S.A. and Al-Hejji, S. (2006) Causes of delay in large construction projects. *International Journal of Project Management*, **24** (4), 349-357.
- Atazadeh, B., Kalantari, M. and Rajabifard, A. (2016) Comparing Three Types of BIM-based Models for Managing 3D Ownership Interests in Multi-level Buildings. In: *Proceedings of the 5th International FIG 3D Cadastre Workshop, Athens, Greece*, pp. 183-198.
- Autodesk (2017) *System requirements for Autodesk Revit 2017 products / Revit Products / Autodesk Knowledge Network*. [Online] Knowledge.autodesk.com. Available at: <https://knowledge.autodesk.com/support/revitproducts/troubleshooting/caas/sfdcarticles/sfdcarticles/System-requirements-for-Autodesk-Revit-2017-products.html> [Accessed 4 Jan. 2018].
- Autodesk (2007) *BIM and Cost Estimating*. [Online] Available at: [http://www.consortech.com/bim2/documents/BIM\\_cost\\_estimating\\_EN.pdf](http://www.consortech.com/bim2/documents/BIM_cost_estimating_EN.pdf) [Accessed 4 Jan. 2018].
- Autodesk (2002) *Building Information Modelling*. [Online] Autodesk Building Industry Solutions. Available at: [http://www.laiserin.com/features/bim/autodesk\\_bim.pdf](http://www.laiserin.com/features/bim/autodesk_bim.pdf) [Accessed 4 Jan. 2018].

- Awwad, R.A. (2013) Surveying BIM in the Lebanese Construction Industry. *International Association for Automation and Robotics in Construction*.
- Azhar, S., Khalfan, M. and Maqsood, T. (2012) Building information modelling (BIM): now and beyond. *Australasian Journal of Construction Economics and Building*, **12** (4) 15-28.
- Azhar, S. (2011) Building Information Modelling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering*, **11** (3) 241-252.
- Azhar, S., Carlton, W.A., Olsen, D. and Ahmad, I. (2011) Building information modelling for sustainable design and LEED rating analysis. *Automation in Construction*, **20** (2) 217-24.
- Aziz, Z. and Algan, T. (2017) From conventional to IT based visual management: a conceptual discussion for lean construction. *Journal of Information Technology in Construction (ITcon)*, **22**, 220-246.
- BCA (2013) *Singapore BIM Guide* [Online]. Building and Construction Authority. Available at: <http://www.corenet.gov.sg> [Accessed 4 Nov. 2013].
- Babic, N. C., Podbreznik, P., and Rebolj, D. (2010). Integrating Resource Production and Construction Using BIM. *Automation in Construction*, **19**(5), 539-543.
- Baiden, B.K. and Price, A.D.F., (2011) The effect of integration on project delivery team effectiveness. *International Journal of Project Management*, **29**(2), pp.129–136.
- Bailey, C. A. (2007) *A Guide to Qualitative Field Research*. 2nd edn. London: Pine Forge.
- Banawi, A.A. (2017) Barriers to Implement Building Information Modelling (BIM) in Public Projects in Saudi Arabia. *Advances in Intelligent Systems and Computing*.
- Barison, M.B. and Santos, E.T. (2011) The competencies of BIM specialists: a comparative analysis of the literature review and job ad descriptions. *Computing in Civil Engineering*. pp. 594-602. (Online). Available at: [http://www.uel.br/pessoal/barison/Artigos\\_Tese/ASCE-2011.pdf](http://www.uel.br/pessoal/barison/Artigos_Tese/ASCE-2011.pdf) [Accessed 4 Jan. 2018].
- Bashir, A.M. (2013), *A Framework for Utilising Lean Construction Strategies to Promote Safety on Construction Sites*. PhD Thesis, University of Wolverhampton, United Kingdom.
- Basit, T. N. (2003) Manual or Electronic: The Role of Coding in Qualitative Data Analysis. *Educational Research*, **45**, 143-154.
- BCIS (2011) *Building Information Modelling Survey Report*. London: Building Cost Information Service (BCIS), Royal Institute of Chartered Surveyors.
- Beiske, B. (2007) *Research Methods: Uses and Limitations of Questionnaires, Interviews and Case Studies*. Munich: GRIN Verlag.
- Bell, J. (2009) *Doing Your Research Project: A Guide for First-time Researchers in Education and Social Science*. 4th edn. Buckingham, UK: Open University Press.
- Bechtel Riyadh Metro, (2016) Riyadh Metro Project. Online. Available at: <http://www.bechtel.com/projects/riyadh-metro/> [Accessed 12 August 2017]
- Bew, M., Underwood J., Wix, J. and Storer, G. (2008) Going BIM in a commercial world. In: Scherer, R. and Zarli, A., *eWork and eBusiness in architecture, engineering and construction*. London: Taylor and Francis Group.

Bew, M. and Underwood, J. (2010) Delivering BIM to the UK Market. In: *Handbook of Research on Building Information Modelling and Construction Informatics: Concepts and Technologies*. New York: IGI Global.

BIM-Management (2013) *Process Map: BIM Model Exchange*. (Online). Available at: <http://www.bimmanager.com/wp-content/uploads/2013/11/BIM-Process-Exchange-IDM.pdf>. [Accessed 8 Jan. 2018].

Bin Zakaria, Z., Mohamed Ali, N., Tarmizi Haron, A., Marshall-Ponting, A.J. and Abd Hamid, Z. (2013) Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach. *International Journal of Research in Engineering and Technology*, **2** (8) 384-395.

Boyatzis, R.E. (1998) *Transforming Qualitative Information*. Sage: Cleveland.

Brand, V. (2009) Empirical Business Ethics Research and Paradigm Analysis. *Journal of Business Ethics*, **86** (4) 429-449.

Braun, V. and Clarke, V. (2006) Using Thematic Analysis in Psychology. *Qualitative Research in Psychology*, **3**, 77-101.

BSI (2010) BS 6079-1:2010 Project management. Principles and guidelines for the management of projects for BIM Level 2. London. British Standards Institution.

BSI (2007) *BIM Level 2. BS 1192:2007. Collaborative production of architectural, engineering and construction information – Code of Practice*. London: British Standards Institution.

Brewer, J.D. (2000) *Ethnography*. Buckingham: Open University Press.

Bryde, D., Broquetas, M. and Volm, J.M. (2013) The project benefits of building information modelling (BIM). *International Journal of Project Management*, **31** (7) 971-980.

Bryman, A. and Bell, E. (2007) *Business Research Methods*. 2nd edn. New York: Oxford University Press.

Bryman, A. and Bell, E. (2011) *Business Research Methods*. 3rd edn. New York: Oxford University Press.

Bryman, A. and Bell, E. (2015) *Business Research Methods*. 4th edn. Oxford: Oxford University Press.

Bryman, A. (2008) *Social Research Methods*. 3<sup>rd</sup> edn. Oxford: Oxford University Press.

Bryman, A. (2012) *Social Research Methods*, 5<sup>th</sup> edn. Oxford: Oxford University Press.

Bubshait, A. A. (1992) Owner involvement in construction projects in Saudi Arabia. *Journal of Management in Engineering*, **8**, (2), 176-185.

BuildingSMART (2010) *Constructing the business case: Building information modelling*. London: British Standards Institution.

BuildingSMART (2011) *BIM in the Middle East: BIM Survey*. BuildingSMART: Sydney, Australia.

BuildingSMART MENA and India (2011) *BIM in the Middle East 2011: The Reality and The Way Forward*. BuildingSMART, International.

BuildingSMART Australasia (2012) *The National Building Information Modelling Initiative (NBI) Report*. BEIIC (The Built Environment Industry Innovation Council).

Bui, N., Merschbrock, C., and Munkvold, BE., (2016) A review of Building Information Modelling for construction in developing countries. *Procedia Engineering*, 164, 487-494

Butkovic, B and Heesom, D. (2017) Towards a Framework for Multi-LOD 4D BIM Simulations. *Proceedings of International Research Conference 2017: Shaping Tomorrow's Built Environment Conference* at The School of the Built Environment, University of Salford, Manchester, United Kingdom.

Business Week, (2006) *Saudi Arabia, Blueprint in the future -Focus on Construction*. No.121. pp 28- 40.

Bynum, P., Issa, R.R.A. and Olbina, S. (2013) Building information modelling in support of sustainable design and construction. *Journal of Construction Engineering and Management*, ASCE, **129** (1) 24-34.

Ciribini, A., Ventura, S. M., and Bolpagi, M. (2015) Informative content validation is the key to success in a BIM based project. *Territ Italia*, 2, 9-29.

Chan, C. (2014) Barriers of Implementing BIM in Construction Industry from the Designers' Perspective: A Hong Kong Experience. *Journal of System and Management Sciences*, **4** (2) 24-40.

Chen, L.J. and Luo, H. (2014) A BIM-Based Construction Quality Management Model and Its Applications. *Automation in Construction*, **46** (10) 64-73.

Chiu, S. (2010) Students' knowledge sources and knowledge sharing in the design studio – An exploratory study. *International Journal of Technology and Design Education*, **20** (1) 27-42.

Choi, J. (2012) *openBIM and Design Information Quality Control*. Korea: Goomi Books Inc.

Ciborra, C. (2004) Encountering information systems as a phenomenon. In: Avgerou, C., Ciborra, C. and Land, F. (eds.) *The social study of information and communication technology: Innovation, actors, and contexts*, pp. 17-37. Oxford: Oxford University Press.

Clarke, A. and Dawson, R. (1999) *Handbook of Evaluation Research/ An Introduction to Principles, Methods and Practice*. London: Sage Publications.

Coates, P., Arayici, Y., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K. (2010) The limitations of BIM in the architectural process. *First International Conference on Sustainable Urbanism*, December 2010, Hong Kong.

Cohen, L., Manion, L. and Morrison K (2000) *Research Methods in Education*. 5th edn. London: Routledge Falmer.

Cook, T. D, and Campbell, D. T. (1979) *Quasi experimentation: Design and analysis for field settings*. Chicago, Rand McNally.

Collins, K. M. T., Onwuegbuzie, A. J. and Jiao, Q. G. (2006) Prevalence of Mixed Methods Sampling Designs in Social Science Research. *Evaluation and Research in Education*, **19** (2) 83-101.

- Collis, J. and Hussey, R. (2003) *Business Research: A Practical Guide for Undergraduate and Postgraduate Students*. Basingstoke, UK: Palgrave Macmillan.
- Collis, J. and Hussey, R. (2009) *Business Research: A Practical Guide for Undergraduate and Postgraduate Students*. 3rd edn. New York: Palgrave Macmillan.
- Creswell, J. W. (2006) *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. 2nd edn. London: Sage Publications.
- Creswell, J. W. (2009) *Research Design: Quantitative, Qualitative and Mixed Methods Approaches*. 3rd edn. London: Sage Publications.
- Creswell, J. W. (2012) *Educational Research: Planning, Conducting, And Evaluating Quantitative and Qualitative Research*. 4th edn. Boston, MA: Pearson.
- Creswell, J. W. (2013) *Qualitative inquiry and research design: Choosing among five approaches*. 3rd edn. Thousand Oaks, CA: Sage.
- Crotty, R. (2016) *The Impact of Building Information Modelling – Transforming Construction*. 2nd edn. New York: Routledge.
- Dastbaz, M., Pattinson, C., Defeo, C. and Akhgar, B. (2015) *Green Information Technology: A Sustainable Approach*. Amsterdam: Elsevier.
- Davies, R. and Harty, C. (2012) Control, surveillance and the ‘dark side’ of BIM. In *Proceedings of the 28th Annual ARCOM Conference, Edinburgh, UK* (Smith SD (ed.)). Association of Researchers in Construction Management, London, UK.
- Dehe, B. and Bamford, D. (2015) Development, test and comparison of two Multiple Criteria Decision Analysis (MCDA) models: A case of healthcare infrastructure location. *Expert Systems with Applications*, 42, 6717-6727.
- De Vaus, D. (2002) *Surveys in Social Research*. 5th edn. London: Routledge.
- Denscombe, M. (2007) *The Good Research Guide for Small Scale Social Research Projects*. 3rd edn. Glasgow: Bell and Bain Ltd.
- Denscombe, M. (2010) *The Good Research Guide for Small Scale Social Research Projects*. 4th edn. London: Open University Press.
- Denzin, N.K. and Lincoln, Y.S. (eds.) (2011), *The Sage Handbook of Qualitative Research*. London: Sage.
- Do, E. (2002) Drawing marks, acts, and reacts: Toward a computational sketching interface for architectural design. *AI EDAM*, 16 (3) 149-171.
- Dong, R.R. (2017) The Application of BIM Technology in Building Construction Quality Management and Talent Training. *EURASIA Journal of Mathematics, Science and Technology Education*. 13 (7) 4311-4317.
- Dore, C. and Murphy, M. (2013) Integration of Historic Building Information Modelling and 3D GIS for Recording and Managing Cultural Heritage Sites, pp. 369-376. In: *Proceedings of the 18<sup>th</sup> International Conference on Virtual Systems and Multimedia: “Virtual Systems in the Information Society”*, 2-5 September 2012, Milan, Italy.
- Drost, E. A. (2011) Validity and Reliability in Social Science Research. *Education Research and Perspectives*, 38 (1) 105-123.

- Eadie, R., Browne, M., Odeyinka, H., McKeown, C. and McNiff, S. (2013) BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction*, **36**, 145-151.
- Eadie, R., Comiskey, D. and McKane, M. (2014) Teaching BIM in a multidisciplinary department. *Proceeding of Education, Science and Innovations*.
- Eadie, R., Odeyinka, H., Browne, M., McKeown, C. and Yohanis, M. (2014) Building Information Modelling Adoption: An Analysis of the Barriers to Implementation. *Journal of Engineering and Architecture*, **2** (1) 77-101.
- Eadie, R., Browne, M., Odeyinka, H., McKeown, C. and McNiff, S. (2014) A survey of current status of and perceived changes required for BIM adoption in the UK. *Built Environment Project and Asset Management*, **5** (1) 4-21.
- Easterby-Smith, M., Thorpe, R. and Lowe, A. (2002) *Management Research: An introduction*. 2nd edn. London: Sage Publications.
- Easterby-Smith, M., Thorpe, R., Jackson, P.R. and Lowe, A. (2008) *Management Research*. 3rd edn. Los Angeles: Sage Publications.
- Eastman, C. (1976) General purpose building description systems. *Computer-Aided Design*, **8** (1) 17-26.
- Eastman, C. (1999) *Building product models: Computer environments supporting design and construction*. Boca Raton, Florida: CRC Press.
- Eastman C., Teicholz P., Sacks R., and Liston K. (2008) *BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers, and Contractors*. New Jersey: John Wiley and Sons, Inc.
- Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2011) *BIM Handbook: a Guide to Building Information Modelling for Owners, Managers, Designers, Engineers, and Contractors*. 2nd edn. Hoboken, New Jersey: John Wiley and Sons, Inc.
- Economy Watch, (2011) Saudi Arabia Economic Statistics and Indicators. (Online). Available at: <http://www.economywatch.com/economic-statistics/country/Saudi-Arabia/> [Accessed 14 Sept. 2017].
- Edwards, G., Li, H. and Wang, B. (2015) BIM based collaborative and interactive design process using computer game engine for general end-users. *Visualization in Engineering*, **3**, 4. (Online). Available at: <https://link.springer.com/article/10.1186/s40327-015-0018-2> [Accessed 4 Jan. 2018].
- El-Ghonemy, A.M.K. (2012) Future sustainable water desalination technologies for the Saudi Arabia: a review. *Renew Sustain Energy Reviews*, **16** (9) 6566-6597.
- El-Sayegh, S.M. and Mansour, M.H. (2015) Risk Assessment and Allocation in Highway Construction Projects in the UAE. *Journal of Management in Engineering*, **31** (6) 04015004.
- Elvin, G. (2007) *Integrated practice in architecture: mastering design-build, fast-track, and building information modelling*. New Jersey: John Wiley and Sons, Inc.
- Enegbuma, W.I., Aliagha, G.U. and Ali, K.N. (2015) Effects of perceptions on BIM adoption in Malaysian construction industry. *Journal of Technology*, **77** (15) 69-75.

- Eriksson, P. and Kovalainen, A. (2008) *Qualitative Methods in Business Research*. London, UK: Sage.
- Fallon, K.K. and Palmer, M.E. (2007) *General Buildings Information Handover Guide: Principles, Methodology and Case Studies*. The National Institute of Standards and Technology, US Dept of Commerce. (NISTIR 7417).
- Farrell, P. (2011) *Writing a Built Environment Dissertation: Practical Guidance and Examples*. Oxford: Wiley-Blackwell.
- Fellows, R.F. (2010) New research paradigms in the built environment. *Construction Innovation: Information, Process, Management*, **10** (1) 5-1.
- Fellows, R.F. and Liu, A.M.M. (2009) *Research Methods for Construction*, 3rd edn. New York: John Wiley and Sons, Inc.
- Fellows, R.F. (2015) *Research Methods for Construction*, 4th edn. New York: John Wiley and Sons, Inc.
- Feilzer, M. Y. (2010) Doing mixed methods research pragmatically: Implications for the rediscovery of pragmatism as a research paradigm. *Journal of Mixed Methods Research*, **4** (1) 6-16.
- Fiori, C. and Kovaka, M. (2009) Defining Megaprojects: Learning from Construction at the Edge of Experience. *American Society of Civil Engineers (ACSE)*, 70.
- Flick, U. (2006) *An Introduction to Qualitative Research*. 3rd edn. London: Sage Publications.
- Flick, U. (2009) *An Introduction to Qualitative Research*. 4th edn. London: Sage Publications.
- Flick, U. (2011) *Introducing research methodology: A beginner's guide to doing a research project*. London: Sage.
- Fong, H. (2009) *BIM Development – Hong Kong and World Wide Trend*. 1st edn. China: AUTODESK.
- Foqué, R. (2011) Building Knowledge by Design. *4th International Meeting on Architectural and Urbanism Research, Valencia*, 1-6. (Online). Available at: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.863.9197&rep=rep1&type=pdf> [Accessed 5 Jan. 2018].
- Forbes Arabia (2005) *Special report on the Saudi Economy*. **33** (67) 21-64.
- Foster, L.L. (2008) *Legal Issues and Risks Associated with Building Information Modelling Technology*. Masters Thesis, University of Kansas, USA.
- Froese, T. M. (2010). The impact of emerging information technology on project management for construction. *Automation in construction*, **19**(5), 531-538.
- Galiano-Garrigos, A., Mahdjoubi, L. and Brebbia, C.A. (2017) Building Information Modelling (BIM) in Design, Construction and Operations II. *WIT Transactions on the Built Environment*. Wessex Institute of Technology, Ashurst, UK: WIT Press.



- Galiano-Garrigos, A. (2017) Building Information Modelling in operations of maintenance at the University of Alicante. *Proceedings of WIT 2nd International Conference on Building Information Modelling (BIM) in Design, Construction and Operations*, Alicante, Spain.
- Gallaher MP, O'Connor AC, Dettbarn Jr JL and Gilday L. (2014) *Cost Analysis of Inadequate Interoperability in US Capital and Facilities Industry*. National Institute of Standards and Technology, (NIST), Gaithersburg, MD, USA, NIST Report.
- Garber, R. (2014) *BIM Design: Realising the Creative Potential of Building Information Modelling*. Chichester, UK: John Wiley and Sons Ltd.
- Gervásio, H., Santos, P., Martins, R. and Simões da Silva, L. (2014) A macro-component approach for the assessment of building sustainability in early stages of design. *Building and Environment*, **73**, 256-270.
- Gerges M. Austin, S. Mayouf, M. Ahiakwo, O. Jaeger, M. Saad, A. Gohary, T.E. (2017) An investigation into the implementation of Building Information Modelling in the Middle East, *ITcon*, 22, pp. 1–15
- Grilo, A. and Jardim-Goncalves, R. (2009) Value proposition on interoperability of BIM and collaborative working environments. *Automation in Construction*, **19**(5), 522-530.
- Gill, J. and Johansson, P. (2010) *Research methods for managers*. 4th edn. Los Angeles: Sage.
- Gledson, B.J. (2016) Hybrid project delivery processes observed in constructor BIM innovation adoption. *Construction Innovation*, **16** (2) 229-246.
- Goubau, T. (2017) *A History of BIM – APROPLAN*. Available at: <https://www.aproplan.com/blog/construction-collaboration/a-history-of-bim> [Accessed 4 Jan. 2018].
- Gomm, R. (2008) *Social Research Methodology: A Critical Introduction*. 2nd edn. Basingstoke: Palgrave Macmillan.
- Granholm, L. (2011). Finland, Norway, Singapore, USA Lead Progress in Construction, Industry Presentation, BIMsight, [online], available from: <http://www.bimsightblog.com/finland-norway-singapore-usa-lead-progress-in-construction-industry> [Accessed 8 Sept 2018].
- Granadeiro, V., Correia, J., Leal, V. and Duarte, J. (2013) Envelope-related energy demand: A design indicator of energy performance for residential buildings in early design stages. *Energy and Buildings*, **61**, 215-223.
- Groenewald, T. (2004) A Phenomenological Research Design Illustrated. *International Journal of Qualitative Methods*. **3** (1) 1-26.
- Guba, E.G. (1990) The Alternative Paradigm Dialog. In: Guba, E.G. (ed.) *The Paradigm Dialog*. Newbury Park, CA: Sage Publications Inc.
- Guba, E. G. and Lincoln, Y. S. (1989) *Fourth Generation Evaluation*. Newbury Park, CA and London: Sage Publications.
- Hair Jr, J. F., Babin, B., Money, A.H. and Samouel, P. (2005) *Essentials of Business Research Methods*, London: John Wiley and Sons.

- Halfawy M, Froese T.M., (2011) Component-based framework for implementing integrated architectural/engineering/construction project systems. *Journal of Computing in Civil Engineering*, **21**(6), 441-452
- Hammond, S. (2006) *Ethnography: Principles in Practice*. London: Taylor and Francis.
- Haponava, T., and Al-Jibouri, S. (2009) Identifying key performance indicators for use in control of pre-project stage process in construction. *International Journal of Productivity and Performance Management*, **58**(2), 160-173.
- Hair, J.F., Black, W.C., Babin, B.J., and Anderson, R.E. (2010) *Multivariate Data Analysis*. Seventh Edition. Prentice Hall, Upper Saddle River, New Jersey.
- Hardin, B. (2008) *BIM and construction management: proven tools, methods, and workflows*. Indianapolis, Indiana: Wiley Publishing Inc.
- Hari, S., Egbu, C. and Kumar, B. (2005) A knowledge capture awareness tool: an empirical study on small and medium enterprises in the construction industry. *Engineering, Construction and Architectural Management*, **12**, (6), 533-567.
- Harty, C. (2008) Implementing innovation in construction: contexts, relative boundedness and actor-network theory. *Construction Management and Economics*, **26** (10), 1029-1041.
- Heather, N. (1996) *Radical Perspectives in Psychology*, Essential Psychology Series, Herriot, P. (ed.). London: Methuen.
- Hinton, P.R., McMurray, I. and Brownlow, C. (2014) *SPSS explained*. 2nd edn. London: Routledge.
- Hogan, R. and Sinclair R., (1996) Intellectual, ideological, and political obstacles to the advancement of organizational science. *Journal of Applied Behavioural Science*, **32** (4) 378-389.
- Hunter, K. and Kelly, J. (2009) *Life cycle costing of sustainable design (RICS)*. London, UK: RICS Research.
- Hussein, M.H. Ahmad, H. Zahrizan, Z. Ali, M. H. (2017) *Factor affecting of BIM technique in the construction firms in Iraq*. In: MATEC Web Conferences International Symposium on Civil and Environmental Engineering (ISCEE 2017), Vol. 103.
- Ibrahim, A.R., Roy, M.H., Ahmed, Z., Imtiaz, G. (2011), An investigation of the status of the Malaysian construction industry. *Benchmarking: An International Journal*, **17** (2) 294-308
- Idoro, G. I. and Iyagba, R. R. (2008) A comparative study of the use of procurement systems in the construction industries of Finland and Nigeria. *The Professional Builder, Journal of the Nigerian Institute of Building*, 40-50.
- Ikediashi, D. I., Ogunlana, S. O. and Alotaibi, A. (2014) Analysis of Project Failure Factors for Infrastructure Projects in Saudi Arabia: A Multivariate Approach. *Journal of Construction in Developing Countries*, **19** (1) 35-52.
- Jackson, M. and Mead Niblo, D (1999) The Role of Qualitative Methodology in Cross-Cultural Research. *Qualitative Research Journal*, **3** (1) 18-27.

- Jacobson, C. and S. O. Choi (2008) Success factors: public works and public-private partnerships. *International Journal of Public Sector Management* **21**(6) 637 - 657.
- Jadid, M. N. (2013) Overcoming Obstacles Facing the Contractors Sector in Saudi Arabia Using a Rank Correlation Method. *The Open Construction and Building Technology Journal*, **7**, 170-181.
- Jadid, M. N. and Idrees, M. M. (2007) Cost estimation of structural skeleton using an interactive automation algorithm: A conceptual approach. *Automation in Construction*, **16** (6) 797-805.
- Jaweed, R. M. (2004). *An Implementation Model for Design-Build (D&B) Project Delivery System*, MSc. Thesis, King Fahd University of Petroleum and Minerals, School of Environmental Design, Dhahran, Kingdom of Saudi Arabia.
- Johnson, R.B. and Turner, L.A. (2003) *Data collection strategies in mixed methods research*. In A. Tashakkori and C. Teddlie (eds.), *Handbook of mixed methods in social and behavioural research*. Thousand Oaks, CA: Sage.
- Jordani, M. (2010) BIM and FM: The Portal to Lifecycle Facility Management. *Journal for Building Information Modelling*, Spring 2010, 13-16.
- Jung, Y. and Gibson, G. E. (1999) Planning for Computer Integrated Construction. *Journal of Computing in Civil Engineering, ASCE*, **13**(4), 217-225.
- Jung, Y. and Joo, M. (2011) Building information modelling (BIM) framework for practical implementation. *Automation in Construction*, **20**, 126-133.
- Jung, W. and Lee, G. (2016) The status of BIM adoption on six continents. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, **9** (5) 444-448.
- Kassem, M., Succar, B. and Dawood, N. (2015), Building Information Modelling: Analyzing Noteworthy Publications of Eight Countries Using a Knowledge Content Taxonomy, *Building Information Modelling, American Society of Civil Engineers*, pp. 329–371.
- Kagioglou, M., Cooper, G., Aouad, G. and Sexton, M. (2000) Rethinking Construction: The Generic Design and Construction Process Protocol. *Engineering, Construction and Architectural Management*, **7** (2) 141–153.
- Kang, Y., O'Brien, W. J. and Mulva, S.P. (2013) Value of IT: indirect impact of IT on construction project performance via best practices. *Automation in Construction*, **35**, 383-396.
- Kang, T. W. and Hong, C. H. (2015) A study on software architecture for effective BIM/GIS-based facility management data integration. *Automation in Construction*, **54**, 25-38.
- Kang, T., Park, S. and Hong, C. (2016) BIM/GIS-based Data Integration Framework for Facility Management. *GEOProcessing 2016: Eighth International Conference on Advanced Geographic Information Systems, Applications, and Services*, pp.100–105.
- Kaner, I., Sacks, R., Kassian, W. and Quitt, T. (2008) Case studies of BIM adoption for precast concrete design by mid-sized structural engineering firms, *Journal of ITcon*, **13**, 303–323.
- Kazi, A. S. (2005) *Knowledge management in the construction industry: a socio- technical perspective*. Pennsylvania, USA: Idea Group Inc (IGI).

Kessinger, K. (2008) *Recognizing the Benefits of Building Information Modelling*. [Online] Available at: <http://www.constructionsoftwarereview.com/recognizing-thebenefits-of-building-information-modeling>. [Accessed 6 Sept. 2015].

Kelly, G., Serginson, M., Lockley, S., Dawood, N. and Kassem, M. (2013) BIM for facility management: a review and a case study investigating the value and challenges. *13th International Conference on Construction Application of Virtual Reality*, London. (Online) Available at: <http://tees.openrepository.com/tees/handle/10149/559310> [Accessed 5 Jan. 2018].

Kerlinger, F.N. and Lee, H.B. (2000) *Foundations of Behavioural Research*. London: Harcourt College Publishers.

Khosrowshahi, F. and Arayici, Y. (2012) Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management*, **19** (6) 610-635.

King Abdullah Economic City (2017) Website Online. Available at: <http://www.kaec.net/> [Accessed 15 August. 2017]

Kim, S., Jin, R., Hyun, C. and Cho, C. (2013) Development of Operation and Maintenance Cost Estimating Model for Facility Management of Buildings. *Journal of the Architectural Institute of Korea*, **29** (1) 11-21.

Kim, K., Yun, J. (2017) A process to divide curved walls in IFC-BIM into segmented straight walls for building energy analysis. *Journal of Civil Engineering and Management*, **22**(3), 333-345.

Kiviniemi, A., Tarandi, V., Karlshøj, R., Bell, H. and Karud, O.J. (2008) *Review of the Development and Implementation of IFC compatible BIM*. Erabuild Report. (Online). Available at: <http://orbit.dtu.dk/files/131997343/Untitled.pdf> [Accessed 6 Jan. 2018].

Kiviniemi, A. (2010) Challenges of Interoperable BIM in a between organization. (Online). Available at: [http://aarch.dk/fileadmin/filer/Sune/Arto\\_Kiviniemi.pdf](http://aarch.dk/fileadmin/filer/Sune/Arto_Kiviniemi.pdf) [Accessed 4 Jan. 2018].

Korkmaz, S., Miller, V. and Sun, W. (2012) *Assessing key dimensions to effective innovation implementation in inter-organizational teams: An IPD Case*. EPOC Conference, Working Paper Proceedings, The Netherlands.

Kothari, C. R. (2004) *Research Methodology: Methods and Techniques*. New Delhi: New Age International.

Krygiel, E, Read, P. and Vandezande, J. (2010) *Mastering Autodesk Revit Architecture 2011*. New York: John Wiley and Sons, Inc.

Ku, K. and Taiebat, M. (2011) BIM Experiences and Expectations: The Constructor's Perspective. *International Journal of Construction Education and Research*, **7** (3) 175-197

Kumar, B. (2012) Building Information Modelling: Road to 2016. *International Journal of 3-D Information Modelling*, **1** (4) 1-7.

Kymmell, W. (2008) *Building Information Modelling: Planning and Managing Construction Projects with 4D CAD and Simulations*. New York: McGraw Hill Construction.

Lang, S.Y.T., Dickinson, J. and Bucha, R.O. (2012) Cognitive factors in design, *Computers in Industry*, 48, pp. 89-98.

- Langroodi, B. and Staub-French, S. (2012) Change Management with Building Information Models: A Case Study. *Construction Research Congress*. Reston, USA: American Society of Civil Engineers. pp. 1182-1191.
- Latiffi, A., Brahim, J., Mohd, S. and Fathi, M. (2015) Building Information Modelling (BIM): Exploring Level of Development (LOD) in Construction Projects. *Applied Mechanics and Materials*, **773-774**, 933-937.
- Lautanala, M., Enkovaara, E., Heikkonen, A. and Taiponen, T. (2013) *Potential Benefits of Information Technology in Construction in Finland: Technical Report*. Civil and Environmental Engineering Dept., Helsinki University, Finland.
- Lee, G. (2013) What Information Can or Cannot be Exchanged? *Journal of Computing in Civil Engineering*, **25** (1) 1-9.
- Lee, N. and Hollar, D.A. (2013) Probing BIM education in construction engineering and management programs using industry perceptions. *ASC Annual International Conference Proceedings*, California Polytechnic State University, San Luis Obispo, USA, pp. 467-476.
- Lee, G., Harrison, K. and Won, J. (2012) Economic Impact of BIM-Assisted Design Validation. *Automation in Construction*, **22** (1) 577-586.
- Lee, S., Peña-Mora, F. and Park, M. (2006) Web-enabled system dynamics model for error and change management on concurrent design and construction projects. *Journal of Computing in Civil Engineering*, **20** (4) 290-300.
- Li, B., Fu, F.F., Zhong, H. and Luo, H.B. (2012) Research on the computational model for carbon emissions in building construction stage based on BIM. *Structural Survey*, **30** (5) 411-425.
- Lincoln, Y. S., Lynham, S. A. and Guba, E.G. (2011) Contractions, and emerging confluences, revisited. In: Denzin, N.K. and Lincoln, Y.S. (eds.), *The Sage Handbook of Qualitative Research*. 4th edn. Thousand Oaks, CA: Sage Publications.
- Logothetis, S., Delinasiou, A. and Stylianidis, E. (2016) Building Information Modelling for Cultural Heritage: A review. In: *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences II.5*, 177-183.
- Lou, E. C. W., and Alshawi, M. (2009) Critical success factors for e-tendering Implementation in construction collaborative environments: people and process issues. *Electronic Journal of Information Technology in Construction*, **14**, 98-109.
- Love, P, Edwards, D and Wood, E (2011) Loosening the Gordian knot: The role of emotional intelligence in construction. *Engineering, Construction and Architectural Management*, **18**(1), 50-65.
- Lu, N. and Korman, T. (2010) Implementation of Building Information Modelling (BIM) in Modular Construction: Benefits and Challenges. *Construction Research Congress 2010*, Canada. USA: American Society of Civil Engineers, pp. 1136-1145.
- Luu, V.T., Kim, S.Y., Tuan, N.V. and Ogunlana, S.O. (2009) Quantifying schedule risk in construction projects using Bayesian belief networks. *International Journal of Project Management*, **27** (1) 39-50.
- McAuley, B., Hore, A.V., Deeney, J. (2013) Public/Private BIM: An Irish Perspective, *Proceedings of the CITA BIM Gathering*, Dublin, 14-15 November 2013, pp. 25-34.

McCuen, T. L. (2008) Scheduling, Estimating, and BIM: a Profitable Combination. *AACE International Transactions*, 1-8.

McGraw-Hill Construction (2008) Building Information Modelling: Transforming Design and Construction to Achieve Greater Industry Productivity, *SmartMarket Report*. (Online). Available at: [http://images.autodesk.com/latin\\_am\\_main/files/mcgraw-hill\\_construction\\_bim\\_smartmarket\\_report\\_december\\_2008.pdf](http://images.autodesk.com/latin_am_main/files/mcgraw-hill_construction_bim_smartmarket_report_december_2008.pdf) [Accessed 8 Jan. 2018].

McGraw-Hill Construction (2012) *The Business Value of BIM for Infrastructure*. [Online] Available at: [http://images.autodesk.com/adsk/files/business\\_value\\_of\\_bim\\_for\\_infrastructure\\_smartmarket\\_report\\_2012.pdf](http://images.autodesk.com/adsk/files/business_value_of_bim_for_infrastructure_smartmarket_report_2012.pdf) [Accessed 4 Jan. 2018].

McGraw-Hill Construction (2013) 2012 Business Value of BIM in North America. *SmartMarket Report*. (Online). Available at: [http://bradleybim.files.wordpress.com/2012/12/2012\\_bim\\_smartmarket\\_report\\_business\\_value\\_of\\_bim\\_in\\_north\\_america.pdf](http://bradleybim.files.wordpress.com/2012/12/2012_bim_smartmarket_report_business_value_of_bim_in_north_america.pdf). [Accessed 15 Dec. 2014].

McGraw Hill Construction (2014) SmartMarket Report: The business value of BIM for construction in major global markets: How contractors around the world are driving innovation with building information modelling. *McGraw Hill Construction*.

McQueen, R. A., Knussen, C. (2012) *Research Methods for Social Science: A practical introduction*. Harlow: Pearson Education.

Mahamadu, A.M., Navendren, D., Manu, P., Joseph, R. and Dziekoski, K. (2017) Addressing challenges to building information modelling implementation in UK: Designers' perspectives. *Journal of Construction Project Management and Innovation*, **7** (1), 1908-1932.

Manu, P. A. (2012) *An investigation into the accident causal influence of construction project features*. PhD thesis, School of Technology, University of Wolverhampton, United Kingdom.

Map of Saudi Arabia (2017), (Online). Available at: <http://mapsof.net/saudi-arabia/saudi-arabia-regions-map> [Accessed 13 Aug. 2017].

Matarneh, R.T. and Hamed, S.A. (2017) Exploring the Adoption of Building Information Modeling (BIM) in the Jordanian Construction Industry. *Journal of Architectural Engineering Technology*, **6**, 189.

Martens, B. and Peter, H. (2004) *ArchiCAD – Best Practice: The Virtual Building Revealed*. Vienna, Austria: Springer Verlag.

Marzouk, M. and Hisham, M. (2012) Applications of Building Information Modelling in Cost Estimation of Infrastructure Bridges, *International Journal of 3-D Information Modelling*, **1** (2) 17-29.

Masood, R., Kharal, M.K.N. and Nasir, A.R. (2014) Is BIM Adoption Advantageous for Construction Industry of Pakistan? *Procedia Engineering*, **77**, 229-238.

Maxcy, S. J. (2003) Pragmatic threads in mixed methods research in the social sciences: The search for multiple modes of inquiry and the end of the philosophy of formalism. In: Tashakkori, A. and Teddlie, C. (eds.), *Handbook of Mixed Methods in Social and Behavioural Research*. Thousand Oaks, CA: Sage. pp. 51-90.

- May, T. (2011) *Social Research: Issues, Methods and Process*. 4th edn. Maidenhead, Berks: Open University Press/McGraw-Hill.
- Mehran, D. (2016) Exploring the Adoption of BIM in the UAE construction industry for AEC firms. *Procedia Engineering*, **145**, 1110-1118.
- Merriam, S.B. (2009) *Qualitative research: A guide to design and implementation*. 2<sup>nd</sup> edn. San Francisco, CA: Jossey-Bass.
- Merna, T. and Njiru, C. (2002) *Financing and Managing Infrastructure Projects*. Hong Kong: Asia Law and Practice Publishing House.
- Mertens, D. M., (2010) *Research and Evaluation in Education and Psychology: Integrating Diversity with Quantitative, Qualitative, and Mixed Methods*. 3rd edn. Thousand Oaks, CA: Sage Publications.
- Messner, J., Saluja, C. and Zikic, N. (2009) *BIM Project Execution Planning Guide*. Computer Integrated Construction (CIC) Research Program, Pennsylvania State University, USA.
- Meng, X. (2012) The effect of relationship management on project performance in construction, *International Journal of Project Management*, **30** (2), 188-198
- MEED (2005) Aramco sets a clear agenda. *Middle East Economic Digest*, **49** (2) 45-6.
- MEED (2009) *Saudi Construction Project Spending*. Middle East Economic Digest, **44** (30) 5.
- MEED (2010) *Special Report Saudi Arabia*. Middle East Economic Digest, **45** (13) 33-33.
- Ministry of Economy and Planning (2009) Riyadh, Saudi Arabia.
- Ministry of Economy and Planning (2010) Central Department of Statistics and Information. Riyadh, Saudi Arabia.
- Ministry of Economy and Planning (2011) *Saudi Arabia: Political, Economic and Social Development Report*. Riyadh, Saudi Arabia.
- Ministry of Economy and Planning (2013) Riyadh, Saudi Arabia.
- Ministry of Economy and Planning (2014) *Ninth Development Plan*. Riyadh, Saudi Arabia.
- Ministry of Finance (2017) *The Saudi Arabian Monetary Agency Annual Report*. Riyadh, Kingdom of Saudi Arabia.
- Ministry of Finance (2012) *2012 Financial Report*. Riyadh, Saudi Arabia.
- Ministry of Finance (2006) Riyadh, Kingdom of Saudi Arabia.
- Ministry of Housing (2014) *Standards of planning and design projects for the Ministry of Housing*. Riyadh, Saudi Arabia. Available at: <http://www.housing.gov.sa/ar/Projects/Pages/standards.aspx> [Accessed 1 Aug. 2015].
- Mitra, S. and Tan, A.W. (2012) Lessons learned from large construction project[s] in Saudi Arabia. *Benchmarking: An International Journal*, **19** (3) 308-324.
- Mohammed, R.E. (2007) *An exploratory system dynamics model to investigate the relationships between errors that occur in construction documents in Saudi Arabia and their*

*possible causes*. Unpublished PhD Thesis, School of the Built Environment, Heriot-Watt University, Edinburgh.

Molnar, E. (2003) *Trends In Transport Investment Funding: Past Present And Future*. UNESCO and CEMT/CS/12.

Monette, D.R., Sullivan, T. J. and DeJong, C. R. (2005) *Applied Social Research: A Tool for the Human Services*. 6th edn. London: Brooks Publishing.

Moody, D. (2007) *Empirical Research Methods*. Melbourne, Australia: Monash University Press.

Morton, D.E (2012) BIM: A transformative technology within the architectural curriculum in Schools of Architecture (Pedagogic Stages of Architectural Education and the Transformative Effect of BIM). *International Journal of 3-D Information Modelling*, **1** (4) 50-68.

Morrell P (2011) *BIM: A Report for the Government Construction Client Group*. Department for Business, Innovation and Skills, London, UK

Motawa, I and Almarshad, A.K. (2015) Case-Based Reasoning and BIM systems for asset management. *Built Environment Project and Asset Management*, **5** (3), 233-247

Motawa, I., Price, A. and Sher, W. (2004) Modelling the implementation of technological innovations in construction. *International Journal of Computer Applications in Technology*, **20** (1/2/3), 78-89.

IGT (2010) *Low Carbon Construction: Innovation & Growth Team (IGT) Final Report*.

(Online) Available at:

[https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/31773/10-1266-low-carbon-construction-IGT-final-report.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/31773/10-1266-low-carbon-construction-IGT-final-report.pdf) [accessed 5 Jan. 2018].

Mubarak, F.A. (1999) Cultural Adaptation to Housing Needs: A Case Study, Riyadh, Saudi Arabia. *IAHS Conference Proceedings*, San Francisco.

Naoum, S. G. (2008) *Dissertation Research and Writing for Construction Students*. 2nd edn. London: Butterworth-Heinemann.

NBS (2014) *National BIM Report 2014*. London: NBS.

NBS (2017) *National BIM Report 2017*. London: NBS.

Newman, I. (1998) *Qualitative-Quantitative Research Methodology: Exploring the Interactive Continuum*. Carbondale, USA: Southern Illinois University Press.

Neuman, W. L. (2006) *Social Research Methods: Qualitative and Quantitative Approaches*. 5th edn. London: Pearson.

Ngowtanasuwan, G. and Hadikusumo, B.H.W. (2017) System dynamics modelling for BIM adoption in Thai architectural and engineering design industry. *Construction Innovation*, **17** (4) 457-474.

Nisbet, N. and Dinesen, B. (2010) *Constructing the business case: Building Information Modelling*. London: British Standards Institution.

O'Brien M. J. and Al-Biqami N. M. (1999) Survey of Information Technology and the Structure of the Saudi Arabian Construction Industry. In: Lacasse, M.A. and Vanier, D. J. (eds.), *8th International Conference on Durability of Building Materials and Components*,



*Volume 4 - Information Technology in Construction, CIB W78 Workshop*. National Research Council of Canada, Ottawa, Canada: NRC Research Press. pp. 2327-2337.

Onwuegbuzie, A.J. and Leech, N.L. (2005) On Becoming a Pragmatic Researcher: Importance of Combining Quantitative and Qualitative Research Methodologies. *International Journal of Social Research Methodology*, **8** (5) 375-387.

Östlund, U. Kidd, L., Wengström, Y. and Rowa-Dewar, N. (2011) Combining Qualitative and Quantitative Research Within Mixed Method Research Designs: A Methodological Review. *International Journal of Nursing Studies*, **48** (3), 369-383.

Othman, A.A. Torrance, J.V. and Hamid, M.A. (2006) Factors influencing the construction time of civil engineering projects in Malaysia. *Engineering, Construction and Architectural Management*, **13** (5) 481-501.

Oxford Business Group (2009) *The Report, Saudi Arabia*.

Oxman, R. (2004) Think-maps: teaching design thinking in design education. *Design Studies*, **25** (1) 63-91.

Padhi, S.S. and Mohapatra, P.K. J. (2010) Centralized bid evaluation for awarding of construction projects - A case of India government. *International Journal of Project Management*, **28** (3), 275-284.

Paruch, R. (2015) *Computer assisted design using robot structural analysis software, from the perspective of BIM*. XIX International School of Computer Aided Design, Manufacturing and Exploitation. Institute of Building Design, Cracow University of Technology, Poland.

Peräkylä, A. (2011) Validity in research on naturally occurring social interaction. *Qualitative Research Journal*, 365-382.

Phua, F. T. T. (2004) Modelling the determinants of multi-firm project success: a grounded exploration of differing participant perspectives. *Construction Management and Economics*, **22** (5), 451-459.

Piccolo, C. (2010) *Weather and Climate in Saudi Arabia* (Online). Available at: <http://www.hziegler.com/locations/middle-east/saudi-arabia/articles/weather-climate-insaudi-arabia.html> [Accessed 12 Oct. 2016].

Pierce, D.R. (2013) *Project Scheduling and Management for Construction*. John Wiley and Sons.

Pike Research LLC (2012) *Building Information Modelling Research Report*. Publishers 2Q.

Podsakoff, P. M., MacKenzie, S. B. and Podsakoff, N. P. (2012) Sources of Method Bias in Social Science Research and Recommendations on How to Control It. *Annual Review of Psychology*, **63**, 539-569.

Porwal, A. and Hewage, K.N. (2013) Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in Construction*, **31**, 204-214.

Proverbs, D. G. and Holt, G. D. (2000) Reducing construction costs: European best practice supply chain implications. *European Journal of Purchasing and Supply Management*, **6**, 149-158.

Quek, J. K. (2012) Strategies and Frameworks for Adopting Building Information Modelling (BIM) for Quantity Surveyors. *Applied Mechanics and Materials*, **174**, 3404-3419.

- Quirk, V. (2012) A Brief History of BIM. (Online). *ArchDaily*. Available at: <https://www.archdaily.com/302490/a-brief-history-of-bim> [Accessed 4 Jan. 2018].
- Race, S. (2013) *BIM Demystified*. 2nd edn. London: RIBA Publishing.
- Rashad, M. (2014) *Saudi Arabia launches new housing scheme to ease shortage*. (Online) Available at: <http://www.reuters.com/article/2014/03/13/saudi-housing> [Accessed 2 Sept 2016].
- Rahman, R.A., Alsafouri, S., Tang, P. and Ayer, S.K. (2016) Building Information Modelling Skills for Career Success. In: *10th BIM Academic Symposium*.
- Reddy, K.P. (2012). *BIM for Building Owners and Developers*. NJ: John Wiley and Sons.
- RIBA Plan of Work (2013) *Planning Ahead – An introduction to the RIBA Plan of Work 2013*. (Online). Available at: <http://www.architecture.com/files/ribaprofessionalservices/practice/general/ribaplanofwork2013preview25-04-13.pdf> [Accessed 16 Oct. 2017].
- Richards, M. (2010) *Building Information Management: A Standard Framework and Guide to BS 1192*. London: British Standards Institution.
- Riese, M. and Shelden, D. (2011) Comprehensive International BIM with full owner involvement. *Journal of Building Information Modelling*, 28-29.
- Robert S.W. (2011) *BIM Content Development*. Hoboken, NJ: Wiley.
- Robson, C. (2002) *Real World Research*. Oxford: Blackwell Publishing.
- Rogers, J., Chong, H-Y., Preece, C., Chai, C.L. and Jayasena, H.S. (2015) *BIM Development and Trends in Developing Countries: Case Studies*. UAE: Bentham Science Publishers.
- Roller, M.R. (2015) *Applied Qualitative Research Design: A Total Quality Framework Approach*. New York: Guilford Press.
- Rosenberg, T. L. (2006) *Building Information Modelling*. (Online). Available at: <http://www.ralaw.com/resources/documents/Building%20Information%20Modeling%20-%20Rosenberg.pdf>. [Accessed 4 Sept. 2017].
- Sabol, L. (2008) Challenges in Cost Estimating with Building Information Modelling. *Real Estate Review*, **36**(3).
- Sacks, R. and Pikas, E. (2013) Building information modelling education for construction engineering and management. I: Industry requirements, state of the art, and gap analysis. *Journal of Construction Engineering and Management*, **139** (11) 04013016.
- Salford University (1999) *Research Methods*. Manchester: University of Salford.
- Samargandi, N., Fidrmuc, J. and Ghosh, S. (2013) Financial development and economic growth in an oil-rich economy: The case of Saudi Arabia. *Economics and Finance Working Paper Series, Working paper No:12-13*. London: Brunel University.
- Sambasivan, M. and Soon, Y.W (2006), Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, **25** (5) 517-526.

Sarhan, J.G., Xia, B., Fawzia, S., Karim, A., (2017). Lean Construction Implementation in the Saudi Arabian Construction Industry. *Construction Economics and Building*, **17** (1) 46-69.

Sarshar, M. and Connolly A. (2013) *The Use of IT in Commercial management of Construction Projects*. School of Built Environment, Liverpool John Moores University

Saudi Arabian Provinces Map (2017), Online. Available at: <https://sites.google.com/site/saudiarabiajj/country> [Accessed 15 August. 2017]

Saudi Arabia Market Information Resource and Directory, (2011) Profile of Saudi Arabia. (Online) Available at: <http://www.saudinf.com/main/countryprofile.htm> [Accessed 2 Sept 2016].

Saudi Press Agency (2017) The official news agency of Saudi Arabia. Online. Available at: <http://www.spa.gov.sa/?lang=en> [Accessed 15 August. 2017]

Saudi Railway Company (2017) Railway Projects. Online. Available at: <http://www.sar.com.sa/Infrastructure/Introduction/Maintaining-Facilities.aspx> [Accessed 15 August. 2017]

Saunders, M., Lewis, P. and Thornhill, A. (2009) *Research methods for business students*. 5th edn. Harlow, UK: Pearson Education.

Saunders, M., Lewis, P. and Thornhill, A. (2012) *Research methods for business students*. 6th edn. Harlow, UK: Financial Times / Prentice Hall.

Saxon, R.G. (2013) *Growth through BIM*. London: Construction Industry Council.

Sbaraini, A., Carter, S. M., Evans, R. W. and Blinkhorn, A. (2011) How to do a grounded theory study: A worked example of a study of dental practices. *BMC Medical Research Methodology*, **11**, 128-138.

Schostak, John F. (2006) *Interviewing and representation in qualitative research projects*. London: Open University Press.

Shadish, W. R., Cook, T. D. and Campbell, D. T. (2002) *Experimental and quasi-experimental designs for generalized causal inference*. Boston: Houghton Mifflin.

Shash, A. and Al-Amir, M. (1997) Information technology in contractors' firms in Saudi Arabia. *Construction Management and Economics*, **15** (2) 187-200.

Shen, W., Hao, Q., Mak, H., Neelamkavil, J., Xie, H., Dickinson, J., and Xue, H. (2010) Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review. *Advanced Engineering Informatics*, **24** (2) 196-207.

Shen, L., Edirisinghe R., and Yang, M. G. (2016) An Investigation of BIM Readiness of Owners and Facility Managers in Singapore: Institutional Case Study. In CIB World Building Congress Tampere, Finland

Shoult, A. (2006) *Doing Business with Saudi Arabia*. 3rd edn. London: Big On Group.

Sidawi, B. and Al-Omairi, S. (2010) 1st International Graduate Research Symposium on the Built Environment, Middle East Technical University, Ankara, Turkey

- Sidawi, B. and Alsudairi, A. (2014), The potentials of and barriers to the utilization of advanced computer systems in remote construction projects: case of the Kingdom of Saudi Arabia, *Visualization in Engineering*.
- Sidawi, B. and Deakin, M. (2013) Diabetes, built environments and (un)healthy lifestyles: The potential of smart city technologies. *Smart and Sustainable Built Environment*, **2** (3) 311-323.
- Silverman, D. (2003) *Interpreting Qualitative Data: Methods for Analysing Talk, Text and Interaction*. 2nd edn. London: Sage Publications.
- Silverman, D. (2013) *Doing Qualitative Research: A Practical Handbook*. London: Sage.
- Singh, V., Gu, N. and Wang, X (2010), A Theoretical Framework of a BIM-based Multi-disciplinary Collaboration Platform. *Automation in Construction*, **20** (2) 134-144.
- Smith, D.K. and Tardif, M. (2007) *BIMSIGAE: Building Information Modelling: A strategic implementation guide for architects, engineers, constructors*. London: John Wiley and Sons.
- Smith, D.K. and Tardiff, M. (2009) *Building information modelling strategic implementation guide for architects, engineers, constructors and real estate asset managers*. Hoboken New Jersey: John Wiley and Sons, Inc.
- Smith, P. (2014) BIM Implementation: Global strategies. *Procedia Engineering*, **85**, 482-492.
- Sodangi, M., Salman, A.F. and Saleem, M. (2017) Building Information Modelling: Awareness Across the Subcontracting Sector of Saudi Arabian Construction Industry. *Arabian Journal for Science and Engineering*. Berlin and Heidelberg: Springer. pp 1–10.
- Soetanto, R., Price, A.D. and Dainty, A.R.J. (2006) Improving management of people in construction, *Proceedings of the Institution of Civil Engineers: Management, Procurement and Law*, **160**, 7-8.
- Snieder R. and Larner, K. (2009) *The Art of Being a Scientist: A Guide for Graduate Students and their Mentors*. Cambridge: Cambridge University Press.
- Sreelakshmi, S., Kantilal, B.S., Roshan, M., Gopinath, S., (2017), A study on the barriers to the implementation of building information modelling. *International Journal of Civil Engineering and Technology*
- Stanley, R. and Thurnell, D.P. (2014) The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand. *Construction Economics and Building*, **14** (1) 105-117.
- Succar, B. (2010) Building Information Modelling Maturity Matrix. In: Underwood, J. & Isikdag, U. (eds.), *Handbook of Research on Building Information Modelling and Construction Informatics: Concepts and Technologies*, New York: IGI Publishing.
- Succar, B., Sher, W. and Williams, A. (2013) An integrated approach to BIM competency assessment, acquisition and application. *Automation in Construction*, **35**, 174-189.
- Sugiharto, A., Hampson, K. D., and Mohamed, S. A. (2002) Factors Influencing Contractor Performance in Indonesia: A Study of Non-Value-Adding Activities. In *International Conference on Advancement in Design, Construction, Construction Management and Maintenance of Building Structure, Bali*.

- Sutherland, I. (2003) Sketchpad a Man-Machine Graphical Communication System. *Transactions of the Society for Computer Simulation*, **2** (5) 3-20.
- Sullivan, G., Pugh, R., Melendez, A. P. and Hunt, W.D. (2010) *Operations and Maintenance Best Practices: A Guide to Achieving Operational Efficiency*. U.S. Department of Energy: Federal Energy Management Program.
- Tahrani, S., Poirier, E.A., Aksenova, G. and Forgues, D. (2015) Structuring the adoption and implementation of BIM and integrated approaches to project delivery across the Canadian AECO industry: Key drivers from abroad. *5th International / 11th Construction Specialty Conference*. Vancouver, Canada.
- Taleb, H.M. and Sharples, S. (2011) Developing sustainable residential buildings in Saudi Arabia: A case study. *Applied Energy*, **88**, 383-391.
- Tekla BIMsight (2017). *Tekla BIMsight Mobile Applications*. [online] Tekla BIMsight. Available at: <https://helpcenter.teklabimsight.com/mobile/windows.jsp> [Accessed 4 Jan. 2018].
- TIMETRIC (2016), Building Information Modelling (BIM) in the Global Construction Market. Construction Intelligence Center (CIC) [Online]. Available at: <https://www.timetricreports.com/report/cn0002mi--market-insight-building-information-modelling-bim-in-the-global-construction-market/> [Accessed 4 Jan. 2018].
- Tardif, M. (2015). *Building Information Modelling*. Owners Perspective
- Trochim, W. M.K. (2006) *Research Methods Knowledge Base*. 3<sup>rd</sup> edn. USA: Atomic Dog Publishing Inc.
- Tseng, I., Moss, J., Cagan, J. and Kotovsky, K. (2008) The role of timing and analogical similarity in the stimulation of idea generation in design. *Design Studies*, **29** (3) 203-221.
- Tuuli, M. M. (2009) Empowerment in project teams: A multilevel examination of the job performance implications. *Construction Management & Economics*, **27** (5), 473-498.
- Turner, A. (1990) *Building Procurement*. London: Palgrave Macmillan.
- Ubaid, G.A. (1991) *Factors affecting Contractor Performance*. MSc. Thesis, King Fahad University of Petroleum and Minerals, Dhahran, Kingdom of Saudi Arabia.
- Underwood, J. and Isikdag, U. (2010) *Handbook of Research on Building Information Modelling and Construction Informatics: Concepts and Technologies*. Hershey, Pennsylvania, USA: IGI Global.
- Underwood, J. and Isikdag, U. (2011) Emerging technologies for BIM 2.0. *Construction Innovation*, **11** (3) 252-258.
- Underwood, J. and F. Khosrowshahi (2012) ICT expenditure and trends in the UK construction industry in facing the challenges of the global economic crisis. *Journal of Information Technology in Construction*, **17**, 26-41
- Underwood, J., Ayoade, O., Khosrowshahi, F., Greenwood, D., Pittard, S., and Garvey, R. (2015) Current position and associated challenges of BIM education in UK higher education. *BIM Academic Forum*. Manchester: University of Salford.

- Usmani, Y.S., Al-Ahmari, A.M.A., (2012) A study to assess significance of project management performance: assessment model in applied projects *International Journal of Applied Systemic Studies (IJASS)*, **4** (3)
- US – Saudi Arabian Business Council (2009) *The Construction Sector in the Kingdom of Saudi Arabia*. (Online). Available at: [https://www.us-sabc.org/files/public/Construction\\_Brochure.pdf](https://www.us-sabc.org/files/public/Construction_Brochure.pdf) [Accessed 12 July. 2016]
- Vanderstoep, S.W. (2009) *Research Methods for Everyday Life: Blending Qualitative and Quantitative Approaches*. New York: Jossey-Bass.
- Vanlande, R., Nicolle, C. and Cruz, C. (2008) IFC and building lifecycle management. *Automation in Construction*. **18** (1) 70-78.
- Vass, S, Gustavsson, T.K. (2017) Challenges when implementing BIM for industry change. *Construction Management and Economics*, 1-14.
- Vogt, B. (2010) *Relating Building Information Modelling and Architectural Engineering Curricula*. Kansas: Kansas State University.
- Wang, X. (2007) Using Augmented Reality to Plan Virtual Construction Worksite. *International Journal of Advanced Robotic Systems*, **4** (4) 501–512.
- WeatherBase, (2014) *Kingdom of Saudi Arabia -Weather Averages*. WeatherBase.
- Wiles, R., Crow, G. and Pain, H. (2011) Innovation in Qualitative Research Methods: A Narrative Review. *Qualitative Research*, **11** (5) 587-604.
- Wilcox, R. R. (2001) *Fundamentals of Modern Statistical Methods: Substantially Improving Power and Accuracy*. New York: Springer.
- Won, J., Lee, G., Dossick, C., and Messner, J. (2013). Where to focus for successful adoption of building information modeling within organizations. *Journal of Construction Engineering and Management*, 139(11).
- Wu, P., Li, H. and Wang, X. (2017) *Integrated Building Information Modelling*. Sharjah, UAE: Bentham Science Publishers.
- Wu, W. and Issa, R.R. (2013) BIM education and recruiting: Survey-based comparative analysis of issues, perceptions, and collaboration opportunities. *Journal of Professional Issues in Engineering Education and Practice*, **140** (2) 04013014.
- Yan, H. and Demian, P. (2008) Benefits and Barriers of Building Information Modelling. [Online] In: Ren, A., Ma, Z. and Lu, X. *Proceedings of the 12th International Conference on Computing in Civil and Building Engineering (ICCCBE XII) & 2008 International Conference on Information Technology in Construction (INCITE 2008)*, Beijing, China: Tingshua University Press.
- Yang, H., Yeung, J.F.Y., Chan, A.P.C., Chiang, Y.H. and Chan, D.W.M. (2010) A critical review of performance measurement in construction, *Journal of Facilities Management*, **8**(4), 269-284.
- Yin, R. K. (2013) *Case Study Research: Design and Methods*. 5th edn. Newbury Park, CA: Sage Publications.

- Yoon, H., Ham, Y., Golparvar-Fard, M. and Spencer, B. F. (2015) Forward-Backward Approach for 3D Event Localization Using Commodity Smartphones for Ubiquitous Context-Aware Applications in Civil and Infrastructure Engineering. *Computer-Aided Civil and Infrastructure Engineering Journal*, **31** (4) 245-260.
- Young, N.W., Jones, S.A. and Bernstein, H.M. (2009) *Building Information Modelling (BIM) Transforming design and construction to achieve greater industry productivity*. New York: McGraw Hill.
- Zhang, J. and Hu, Z. (2011) BIM- and 4D-based integrated solution of analysis and management for conflicts and structural safety problems during construction: 1. Principles and methodologies. *Automation in Construction*, **20**, 155-166.
- Zhao, D., McCoy, A.P., Bulbul, T., Fiori, C. and Nikkhoo, P. (2015) Building Collaborative Construction Skills through BIM-integrated Learning Environment[s]. *International Journal of Construction Education and Research*, **11** (2) 97-120.
- Zhou, J., Love, P.E.D., Wang, X., Teo, K.L. and Irani, Z. (2013) A review of methods and algorithms for optimizing construction scheduling. *Journal of the Operational Research Society*, **64** (8) 1091-1105.
- Zikmund, W. G., Babin, B. J., Carr, J. C. and Griffin, M. (2010) *Business Research Methods*. 8th edn. Boston, USA: Cengage Learning.

# APPENDIX 1 QUESTIONNAIRE AND COVER LETTER



## RESEARCH PARTICIPATION COVER LETTER

27<sup>th</sup> April, 2016

[S.Alhumayn@wlv.ac.uk](mailto:S.Alhumayn@wlv.ac.uk)

**Dear Potential Respondent,**

My name is Saud Alhumayn and I am a PhD research student of the University of Wolverhampton, UK. I am researching an area of Construction Management, under the supervision and guidance of Professor Issaka Ndekugri and Dr Ezekiel Chinyio. I am currently in the process of gathering data for my research entitled: *An Investigation of the Effective Use of BIM in the Kingdom of Saudi Arabia and the Development of Strategies for Overcoming any Associated Barriers.*

I would like to invite you to participate in the above research project as you have been identified firstly, as working with a construction organization that is operating in Saudi Arabia and secondly, having a familiarity with and understanding of BIM.

Completion of the questionnaire will take approximately 30-45 minutes and all questions can be answered by following the simple instructions. Any information you provide will remain confidential and anonymous. Your responses will be used to compile and analyze statistical data in order to gain a better understanding of this area of interest. No names of individuals or their organizations will be mentioned in any report of this research.

Please note that all data gathered for this research will be stored securely and destroyed after the research thesis has been submitted. My supervisory team and I will be the only people who will have access to this data. Please note that you can complete the questionnaire online at <https://www.surveymonkey.com/r/78DBWLB> or via the attached hard copy. Either way, please endeavour to complete the survey by 27th July, 2016. If you are completing the paper copy, then please return it to me directly. Once completed, a summary of the results will be available on the conclusion of the research. If you wish to obtain a copy of these results, please indicate this and provide your contact details.



Thank you for taking the time to consider this invitation and if you choose to participate in this research, I would like to extend my personal gratitude; your contribution is greatly appreciated.

27 ابريل 2016

هذا الاستبيان جزء من دراسة الدكتوراه الهدف من الدراسة هو "التحقق من جدوى استخدام نمذجة معلومات البناء في المملكة العربية السعودية وايجاد الاستراتيجية المناسبة لأي عوائق".  
أعلاه مشروع بحثي وأختيار المشاركين تم بناء على:  
أولاً: العمل في بيئة البناء والأنشاءات في المملكة العربية السعودية.  
ثانياً: وجود دراية ومعرفة في نمذجة معلومات البناء (BIM).  
وأود أن أدعوكم للمشاركة في المشروع البحثي الذي سوف يستغرق هذا الاستبيان حوالي 20 -30 دقيقة من وقتكم وجميع الأسئلة يمكن الإجابة عليها عن طريق اتباع التعليمات البسيطة.  
إن جميع المعلومات التي سوف تقدمها تظل سرية ومجهولة المصدر. وسيتم استخدام ردودكم على تجميع وتحليل البيانات الإحصائية من أجل الحصول على الفائدة والفهم الافضل لهذه الدراسة. لن يتم ذكر اي أسماء سواء الأفراد أو المنظمات في أي تقرير من هذا البحث.  
يرجى ملاحظة أن جميع البيانات التي تم جمعها لهذا البحث سيتم تخزينها في مكان آمن وسوف يتم تدميرها بعد أن يتم تقديم الأطروحة البحثية. يرجى ملاحظة أنه يمكنك تعبئة الاستبيان على الانترنت عبر الرابط <https://www.surveymonkey.com/r/78DBWL8>  
أو عبر النسخة المطبوعة المرفقة. وفي كلتا الحالتين، يرجى إكمال الاستبيان قبل 27 يوليو 2016. إذا انتهيت من النسخة الورقية يرجى إعادتها لي مباشرة.  
ملخص النتائج سوف يكون متاح في ختام هذا البحث. إذا كنت ترغب في الحصول على نسخة من هذه النتائج، يرجى الإشارة إلى ذلك، وتقديم تفاصيل الاتصال الخاصة بك.

شكرا لأخذنا جزء من وقتكم للنظر في هذا الاستبيان، أود أن أعرب لكم عن امتناني الشخصي؛ لمساهمتكم.  
تفضلوا بقبول فائق الاحترام،

Yours sincerely,

SAUD ALHUMAYN

اطيب التحيات

طالب الدكتوراه: سعود الحمين

جامعة ولفرهامبتون

المملكة المتحدة

## QUESTIONNAIRE (As Used)

**Research Title: An Investigation of the Effective Use of BIM in the Kingdom of Saudi Arabia and the Development of Strategies for Overcoming any Associated Barriers.**

عنوان الرسالة: التحقق من جدوى استخدام نمذجة معلومات البناء في المملكة العربية السعودية وإيجاد الاستراتيجيات المناسبة لأي عوائق.

### Instructions:

- Please answer all questions.
- Given below are a number of statements/questions associated answer. Select the most appropriate answer/s by putting 'X' in the appropriate box.
  - Sometimes, none of the given statements may exactly describe your situation or understanding. When that is the case, you can provide an alternative answer which describes you, or your situation, more accurately.
  - Please note that there is no right or wrong answer/s.
- Please read each question carefully before selecting your answer/s as some may require you to tick more than one response.

### تعليمات:

- الرجاء الإجابة على جميع الأسئلة.
- في الاستبيان التالي مجموعة من الاسئلة يرجى الاختيار عن طريق وضع 'X' في الخانة المناسبة.
- في بعض الاحيان لا تجد الاختيار المناسب الذي يتوافق مع رؤيتك وفهمك في هذه الحالة يرجى اختيار اقرب اختيار يتوافق مع فهمك للسؤال ورؤيتك.
- يرجى ملاحظة أنه لا يوجد خطأ او صواب في الاجابات.
- يرجى قراءة كل سؤال بدقة قبل اختيار إجابتك كما في بعض الاسئلة قد يكون متاح اختيار اكثر من اجابة.

### Part 1 - Demographic Information

الجزء 1) معلومات عامة  
ماهي فنتك العمرية:

#### 1) What is your age group?

18 – 25 years	26 – 35 years	36 – 45 years	46 – 55 years	Over 55 years

#### 2) What is your highest formal educational qualification?

ما هو مؤهلك التعليمي؟

Secondary/High School متوسط/ ثانوي	College دبلوم	University Bachelor بكالوريوس	University Masters ماجستير	University PhD دكتوراه	Post- Doctoral باحث بعد الدكتوراه

**3) How many years of work experience do you have pertaining to construction projects?**

كم عدد سنوات خبرتك في مشاريع البناء ؟

1 to 5 years	6 to 10 years	11 to 15 years	16 to 20 years	21 to 25 years	More than 25 years

**4) How many years of work experience do you have pertaining to construction projects in Saudi Arabia?**

كم عدد سنوات خبرتك في مشاريع البناء في السعودية؟

1 to 5 years	6 to 10 years	11 to 15 years	16 to 20 years	21 to 25 years	More than 25 years

**5) Which of these describes your organization?**

أي من هذه يمثل نشاط الجهة التي تعمل لديها ؟

Contractor مقاولات	Consultant استشارات	Client مالك	Clients representative ممثّل للمالك
Other type - please specify.....			اخرى .....

**6) What is your current position, or job description, within the organization?**

ما هو منصبك الوظيفي الحالي في الجهة التي تعمل لديها ؟

Director مدير عام	Project Manager مدير مشروع	Constructio n Manager مدير انشاءات	Archite ct معماري	Planning Team Member فريق التخطيط	Civil Engineer مهندس مدني	Quantity Surveyor حساب كميات	Safety Manager مدير السلامة
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Other description - please specify..... منصب اخر .....							

**7) What is the number of employees in your organization?**

كم عدد الموظفين في الجهة التي تعمل لديها ؟

1 to 10	11 to 49	50 to 249	250 to 999	More than 1000

**8) What types of construction project does your organization undertake?**

ما هي أنواع المشاريع التي تعمل عليها الجهة التي تعمل لديها؟

Public sector works مشاريع عامة	Private sector works مشاريع خاصة	Works for both the Public and Private sectors مشاريع عامة وخاصة معا

**9) Your organization specializes in which type/s of construction projects? (NB: You may select more than one)**

الجهة التي تعمل لديها مختصة بأي نوع من انواع المشاريع؟ (يمكن اختيار اكثر من اجابة)

Commercial Buildings مباني تجارية	Industrial Buildings مباني صناعية	Governmental Buildings مباني حكومية	Residential Buildings مباني سكنية	Roads and Transportation طرق ومواصلات	Dams/ Infrastructure سدود وبنية تحتية
Other types - please specify..... أخرى .....					

**10) What is the highest cost of projects in which your organization has been involved? ما**

هو اكبر مشروع من ناحية القيمة عملت فيه الجهة التي تعمل لديها ؟

Small and Medium Sized Projects مشاريع صغيرة ومتوسطة	Large Projects مشاريع كبيرة	Mega Projects مشاريع عملاقة
1- 50 million Saudi Riyals	51-250 million Saudi Riyals	+250 million Saudi Riyals أكثر من 250 مليون ريال سعودي

من 1-50 مليون ريال سعودي	من 51-250 مليون ريال سعودي	

## Part 2 – The Use of BIM in the Construction Industry of Saudi Arabia

الجزء 2 - استخدام نمذجة معلومات البناء في المشاريع في المملكة العربية السعودية

### 11) How familiar are you with 'Building Information Modelling' (BIM)?

كيف تقيم مستواك في استخدام نمذجة معلومات البناء ؟

Not aware ليس لدي ادنى فكرة	Somewhat Familiar قليل المعرفة	Fairly familiar متوسط المعرفة	Well versed in it متمكن الى حد ما	An expert user مستخدم خبير

### 12) How many BIM training/coaching sessions have you attended within your organization? (Include in-house training, short courses, workshops and seminars in your response)

كم عدد الدورات التدريبية لنمذجة معلومات البناء التي قمت بحضورها عن طريق جهة العمل التي تعمل لديها (يشمل التدريب الداخلي، دورات قصيرة، ورش العمل والندوات)

None	1	2	3	4	More than 4

### 13) How many BIM training/coaching sessions have you attended outside your organization? (Include in-house training, short courses, workshops and seminars in your response)

كم عدد الدورات التدريبية لنمذجة معلومات البناء التي قمت بحضورها خارج جهة العمل التي تعمل لديها (يشمل التدريب الداخلي، دورات قصيرة، ورش العمل والندوات)

None	1	2	3	4	More than 4

### 14) Please indicate how many projects have been developed using BIM within your organization?

كم عدد المشاريع التي تم تطويرها باستخدام نمذجة معلومات البناء في الجهة التي تعمل لديها؟

None (Zero)	1-5 Projects	6-10 Projects	11-15 Projects	16-20 Projects	Over 20 Projects

**15) Are you aware of any BIM software or tool?**

هل لديك معرفة في اي من تطبيقات نمذجة معلومات البناء؟

Answer	Yes نعم	No لا
Tick on this row		
Action	Continue to question 16 اجب على السؤال 16	Skip to question 16 لا تجب على السؤال 16

**16) Please indicate the frequency with which your company uses BIM software/tools/applications:**

ما مدى استخدام برامج نمذجة معلومات البناء (BIM) / أدوات / التطبيقات:

Never Used مطلقا	Occasionally Used نادرا	Frequently Used احيانا	Always Used دائما

If never used please Skip (Q17)

إذا لم تستخدم مطلقا لا تجب على السؤال (17)

**17) Please indicate the reasons for using BIM within your organization: (You may select more than one)**

ما هي أسباب (دوافع) استخدام نمذجة معلومات البناء (BIM) في الجهة التي تعمل لديها: (يمكن اختيار أكثر من إجابة)

It creates views and schedules Automatically يقترح حلول وجداول زمنية تلقائيا	It reflects changes instantly in all drawings and schedules يعكس التغييرات على الفور في جميع المخططات والجداول	Less paperwork and multiple files are avoided تقليل الأعمال الورقية وتجنب تعدد الملفات	It is compatible with data exchange standards for inter-operability متوافق مع معايير تبادل البيانات للتشغيل المتبادل	It is required by our clients مطلوب من قبل المالك	It is required by other project team Members مطلوب من قبل فريق عمل في المشروع
Other reasons - please specify..... أخرى .....					

18) Please indicate which of the following processes in your opinion are improved/streamlined by using BIM instead of 2D/3D CAD: (You may select more than one)

اي من هذه العمليات من وجهة نظرك تتحسن بعد استخدام نمذجة معلومات البناء بدل من البناء بالطرق التقليدية ثنائي وثلاثي الابعاد: (يمكن اختيار اكثر من اجابة)

Production of drawings and schedules الرسومات والجدول الزمنية	Visualization رؤية المشروع المستقبلية	Programming برمجة المشروع	Costing التكلفة	Energy Analysis تحليل الطاقة	Greater collaboration with consultants and other project team members التعاون مع الاستشاريين وغيرهم من أعضاء فريق المشروع	I do not know لا أعلم
Other reasons - please specify..... أخرى .....						

19) Please indicate the software that your company currently uses for managing construction projects: (You may select more than one)

ما هي البرامج التي تستخدمها حاليا جهة عملك لإدارة مشاريع البناء: (يمكن اختيار اكثر من اجابة)

Microsoft Office Project [Web interface with Office, Outlook and Share point integration] مايكروسوفت أوفيس بروجكت	Primavera [Project portfolio management] بريميفيرا	Matchware MindView [Spreadsheet-type layout, and mind map option to see the project in visuals] ماتشوير مايند فيو	RationalPlan Multi Project [Features include management of resources and budgets as well as multiple projects with an interactive Gantt chart] راشونال بلان ملتي بروجكت	BIM Software (Such as Autodesk Revit, Bentley, and Tekla etc.) [Project Design] تطبيقات نمذجة معلومات البناء مثل اوتوديسك ريفيت او بنتلي او تكلا	None Of These لا شيء من هذه
Use of other software - please specify..... أخرى .....					

**20) Please indicate the specific BIM software used by your company where applicable:  
(You may select more than one)**

ما هي برامج نمذجة معلومات البناء (BIM) التي تستخدمها جهة عملك حالياً: (يمكن اختيار أكثر من إجابة)

Autodesk including (Revit Architectu re Structure and MEP Autodesk Naviswor k) اوتوديسك ويشمل (ريفيت للمعماري والانشائي واوتوديسك نافيسوورك)	Bentley including (Bentley Architectu re and Bentley Navigator ) بنتلي ويشمل (بنتلي للمعماري وبنتلي نافيقاتور)	Tekla including (Tekla Structures ) تكلا ويشمل (تكلا الانشائي)	Graphisoft including (ArchiCA D) جرافيسوفت ويشمل (أرشكاد)	Gehry Technologie s Including (Digital Project and Extensions) جهرى تكنولوجيا ويشمل (ديجيتال بروجيكت و اكستنشن)	Nemetsche k including (All plan Architectur e) نيميتشيك ويشمل (جميع مخططات العمارة)	None Of Thes e لا شئ من هذه
Other type - please specify..... أخرى.....						

**Further Instructions:**

**For parts 3, 4 and 5 of this questionnaire please answer on a scale of 1-5, where:**

**1 is 'strongly disagree', 2 is 'disagree', 3 is 'neutral', 4 is 'agree' and 5 is 'strongly agree'.**

تعليمات:

للاجزاء 3 و 4 و 5 من هذا الاستبيان الرجاء الإجابة على مقياس من 1-5، حيث:  
1- 'لا أوافق بشدة'، 2- 'لا أوافق'، 3- 'محايد'، 4- 'أوافق' و 5- 'أوافق بشدة'.



### Part 3 - Awareness and Benefits of BIM in the Construction Industry of Saudi Arabia

الجزء 3 – الوعي وفوائد نمذجة معلومات البناء في صناعة البناء في المملكة العربية السعودية.

	Please provide your opinion to the following questions or statements يرجى تقديم رأيك على هذه الاسئلة	Your opinion				
		1	2	3	4	5
21	There is a growing awareness of BIM usage in Saudi Arabia. هناك وعي متزايد لاستخدام نمذجة معلومات البناء في المملكة العربية السعودية.					
22	There is a growing demand for BIM usage in Saudi Arabia. هناك طلب متزايد لاستخدام نمذجة معلومات البناء في المملكة العربية السعودية.					
23	The using of BIM will shorten the overall project timescale. نمذجة معلومات البناء تساعد على تقصير الجدول الزمني للمشروع.					
24	The use of BIM reduces the overall project cost. استخدام نمذجة معلومات البناء يقلل من التكلفة الإجمالية للمشروع.					
25	The use of BIM minimizes construction conflicts. استخدام نمذجة معلومات البناء تقلل النزاعات في المشاريع					
26	The use of BIM makes information more accessible to project team members. نمذجة معلومات البناء تجعل المعلومات في متناول جميع اعضاء المشروع.					
27	The use of BIM can improve the design of a building. استخدام نمذجة معلومات البناء يساعد على تحسين التصميم للمشروع					
28	The use of BIM makes communication more straightforward. استخدام نمذجة معلومات البناء يجعل التواصل بين اعضاء الفريق اسهل.					
29	The use of BIM makes project sequencing/scheduling easier. استخدام نمذجة معلومات البناء يسهل تسلسل أنشطة المشروع وجدولتها					
30	Full project Life Cycle evaluations can be conducted using BIM. يمكن اجراء عمليات تقييم دورة حياة كاملة للمشروع باستخدام نمذجة					

	معلومات البناء.					
31	A real time model of the project can be visualized with the use of BIM. يمكن تصور الوقت الحقيقي للمشروع باستخدام نمذجة معلومات البناء					

**Q32 Comment generally about the benefits of using BIM in the KSA:**

بصفة عامة تحدث عن فوائد استخدام نمذجة معلومات البناء في المملكة العربية السعودية:

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**Q33 Comment generally about the awareness of BIM in the KSA:**

بصفة عامة تحدث عن الوعي في استخدام نمذجة معلومات البناء في المملكة العربية السعودية:

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#### **Part 4 - Barriers to Adopting BIM in the Saudi Construction Industry**

الحواجز أو الموانع التي تحول دون اعتماد نمذجة معلومات البناء في المملكة العربية السعودية

No.	Please provide your opinion to the following questions or statements:  يرجى تقديم رأيك على هذه الاسئلة	Your opinion				
		1	2	3	4	5
34	BIM is not required by clients. نمذجة معلومات المباني غير مشروطة من قبل العميل Clients do not request the use of BIM software in developing architectural and engineering designs and analysis. العميل لا يطلب استخدام نمذجة معلومات البناء لتطوير التصميم المعمارية والانشائية وعمليات التحليل					
35	There is no (legal) practice guide to support the use of BIM in Saudi Arabia. لا يوجد هناك دليل استخدام قانوني لدعم مستخدمين نمذجة معلومات البناء في السعودية.					

	<p>No legal backing as to who owns the model and how the model will be exchanged among the team members.</p> <p>لا يوجد سند قانوني على من يمتلك النموذج وكيف سيتم تبادل النموذج بين أعضاء الفريق.</p>				
36	<p><b>BIM is not required by team members such as architects and engineers.</b></p> <p>نمذجة معلومات البناء غير مطلوبة من قبل أعضاء الفريق الآخرين مثل المماريين والمهندسين.</p> <p>Team members do not request the use of BIM to develop a project design model or to extract information.</p> <p>أعضاء الفريق لا يطلبون استخدام نمذجة معلومات المباني لتطوير نموذج التصميم في المشروع أو لاختذ معلومات من النماذج.</p>				
37	<p><b>BIM software are too expensive.</b></p> <p>برامج نمذجة معلومات البناء باهظة الثمن</p> <p>Software prices are too high to the extent that only mega firms can afford their user license.</p> <p>أسعار البرمجيات مرتفعة جدا لدرجة أنه ليس هناك سوى الشركات الكبرى التي تستطيع الحصول عليها.</p>				
38	<p><b>BIM is difficult to learn.</b></p> <p>من الصعب تعلم نمذجة معلومات البناء.</p> <p>It takes time to learn all the tools in BIM and it is difficult to understand its functions.</p> <p>يستغرق وقتا لتعلم جميع الأدوات في برامج نمذجة معلومات البناء وأنه من الصعب أن نفهم وظيفة القوائم المختلفة على البرامج.</p>				
39	<p><b>The non-availability of a parametric library hinders the uptake of BIM.</b></p> <p>عدم توفر مكتبة او كود خاص لنمذجة معلومات المباني</p> <p>Parametric object library that will enhance easier development of models using local building standard codes is not available in Saudi Arabia.</p> <p>مكتبة او كود التي من شأنها تعزيز وتسهيّل التنمية في النموذج باستخدام قوانين البناء القياسية المحلية غير متوفرة في المملكة العربية السعودية.</p>				
40	<p><b>It takes a longer time to develop a BIM model.</b></p> <p>يستغرق وقتا طويلا لتطوير نموذج معلومات البناء</p> <p>More time is spent in developing a BIM model compared with just using 2D CAD.</p> <p>يستغرق الكثير من الوقت لتطوير نموذج معلومات البناء أكثر من الطريقة التقليدية</p>				
41	<p><b>There is a lack of competent staff in Saudi Arabia to operate the BIM software.</b></p> <p>هناك نقص في الموظفين الأكفاء لتشغيل برمجيات نمذجة معلومات البناء</p> <p>Majority of the available personnel are not conversant with</p>				

	BIM, and those who are competent, are not easy to reach and are very expensive to hire or employ. الغالبية العظمى من الأفراد المتاحين ليسوا على المام كامل في نمذجة معلومات البناء، وأولئك الذين يتمتعون بالكفاءة ليس من السهل الوصول إليهم، ومكلف جدا لاستئجار أو توظيف احدهم.					
42	<b>BIM does not add much value to our organization.</b> نمذجة معلومات المباني لا تضيف قيمة كبيرة للجهد التي انتمى لها. BIM is not believed to add value to the work done by our organization. لا اعتقد ان نمذجة معلومات المباني تضيف قيمة إلى العمل الذي تقوم به في الجهد التي انتمى لها					

**Q43 Comment freely on any other barriers to the use BIM in the KSA:**

هل ترى ان هناك اي عوائق اخرى تمنع استخدام نمذجة معلومات البناء في المملكة العربية السعودية:

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**Part 5 - Strategies for the Greater Adoption of BIM in the Saudi Construction Industry**

الجزء 5- الاستراتيجيات الكبرى لاعتماد نمذجة معلومات البناء في المملكة العربية السعودية:

	Please provide your opinion to the following questions or statements:  يرجى تقديم رأيك على هذه الاسئلة	Your opinion				
		1	2	3	4	5
44	<b>The importance of BIM should be further promoted with construction clients in KSA.</b> أهمية نمذجة معلومات البناء يجب ان تبين لملاك المشاريع في السعودية Service providers should embark on mass organization of workshops, seminars and symposia on BIM. يجب على مقدمي خدمات نمذجة معلومات البناء الشروع في توضيح وبيان أهمية نمذجة معلومات البناء					
45	<b>The use of BIM should be regulated.</b> وضع التشريعات اللازمة لاستخدام نمذجة معلومات البناء The Saudi Government should introduce a policy that will					

	encourage, and subsequently oblige, construction organizations and professionals to use BIM for all designs. على الحكومة السعودية ان تشجع وتفرض على جميع المؤسسات الحكومية وغير الحكومية ذات العلاقة والمختبرين في البناء باستخدام نمذجة معلومات البناء				
46	<b>The training of construction staff on using BIM is needed now.</b> الحاجة العاجلة الى تدريب الكوادر على نمذجة معلومات البناء In house training and short courses regarding BIM should be encouraged by all Saudi construction organizations. التدريب في المنزل او عقد دورات قصيرة بشأن نمذجة معلومات البناء ينبغي ان يكون من قبل جميع المنظمات في البناء السعودي				
47	<b>BIM should be introduced in the curricula of Saudi Arabian universities.</b> نمذجة معلومات البناء ينبغي ان تكون ضمن الخطة الدراسية في الجامعات السعودية Compulsory teaching of BIM in both Undergraduate and Postgraduate courses of Architecture and Construction Management. التعليم الإلزامي لنمذجة معلومات البناء في الدراسة الجامعية والدراسات العليا في الهندسة المعمارية والهندسة المدنية				
48	<b>More efforts are needed to make BIM inter-operable.</b> الحاجة لمزيد من الجهد لجعل نمذجة معلومات البناء قابلة للتشغيل Development of local parametric library embedded in a national BIM server.				
49	<b>Adopting BIM will give Saudi construction organizations an added value.</b> اعتماد نمذجة معلومات البناء سوف يعطي منظمات التشييد السعودي قيمة اكبر				
50	<b>The changes needed by Saudi organizations in order to adopt BIM are too problematic.</b> الإجراءات اللازمة في المؤسسات الحكومية وغير حكومية لاعتماد نمذجة معلومات البناء معقدة.				
51	<b>The Saudi Government specifically and actively provides support to encourage the adoption of BIM by construction organizations.</b> تقديم الحكومة السعودية للدعم المعنوي هل يشجع لاعتماد نمذجة معلومات البناء من قبل المؤسسات الحكومية وغير حكومية.				

52	<p><b>The Saudi Government specifically provides financial subsidy to promote the adoption of BIM by construction organizations.</b></p> <p>تقديم الحكومة السعودية للدعم المالي بنشاط يشجع اعتماد نمذجة معلومات البناء من قبل المؤسسات الحكومية والغير حكومية.</p>					
53	<p><b>A law is needed to compel practitioners to use BIM.</b></p> <p>هل نحن بحاجة الى قانون يجبر المؤسسات الحكومية والغير حكومية على استخدام نمذجة معلومات البناء</p>					

**Q54 Comment freely on any other effective strategies for adopting BIM in the KSA:**

هل هناك اي استراتيجيات فعالة أخرى لاعتماد نمذجة معلومات البناء في المملكة العربية السعودية:

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**END OF QUESTIONNAIRE**

**THANK YOU AGAIN FOR YOUR CO-OPERATION WITH AND RESPONSES TO  
THIS SURVEY.**

**Please return your completed questionnaire to:**

**Saud Alhumayn**

**+966534448885**

# **APPENDIX 2 INTERVIEW QUESTIONS, COVER LETTER AND CONSENT FORM**

## **INVITATION LETTER TO RESEACH PARTICIPANTS**

**Saud Alhumayn**  
**University of Wolverhampton**  
[S.Alhumayn@wlv.ac.uk](mailto:S.Alhumayn@wlv.ac.uk)  
**20 Dec 2016**

**An Investigation into the extent of the use of BIM in the Saudi Arabian construction industry, and the barriers to its use, and to propose strategies for its effective implementation or adoption**

Dear Potential Participant,

My name is Saud Alhumayn, and I am a PhD Research Student at the University of Wolverhampton working under the supervision of Dr Ezekiel Chinyio and Prof. Issaka Ndekugri. As a part of my research I will be carrying out a set of interviews to help to gain further insight into the problem of BIM adoption and implementation in the construction industry of Saudi Arabia.

I would like to invite you to participate in the above mentioned research, as you have been identified as a Saudi Arabian construction industry professional. If you agree to participate you will be asked to:

- Participate in an interview (of maximum 45-60 minutes duration) with me to answer questions regarding the adoption of BIM in construction organizations in Saudi Arabia in terms of the benefits of BIM and the type of strategies that can be put in place for its implementation.
- Questions will be topic specific and not of a personal nature, and you will not be asked to reveal any information which your organization would regard as sensitive and not for public disclosure.
- Please complete the attached consent form and return it to me.

With your agreement, interviews will be recorded then transcribed. You may review, edit or erase the transcripts and recordings of your interview if you wish to do so. Recordings will then be destroyed. Your responses will be treated as confidential and computer transcripts will not contain references to any personal names (including yourself) or organizations, and all data will be stored securely.

Once completed a summary of results will be available at the conclusion of the research study. If you wish to obtain a copy of these results, please provide your contact details. Please note that all data gathered for this research will be stored securely and destroyed after the dissertation has been submitted. My supervisors and I will be the only people who will have access to this data.

Thank you for taking time to consider this invitation and if you choose to participate in this research I would like to extend my personal gratitude: your contribution is greatly appreciated.

**Yours sincerely**

**SAUD ALHUMAYN**



## RESEACH PARTICIPATION: CONSENT FORM FOR INTERVIEWEES

**Saud Alhumayn**

**University of Wolverhampton**

[S.Alhumayn@wlv.ac.uk](mailto:S.Alhumayn@wlv.ac.uk)

**20 Dec 2016**

**An Investigation into the extent of the use of BIM in the Saudi Arabian construction industry, and the barriers to its use, and to propose strategies for its effective implementation or adoption**

### CONSENT STATEMENT

- I agree to participate in the above research project and give my consent freely.
- I understand that the project will be conducted as described in the invitation Letter, a copy of which I have retained.
- I understand that I can withdraw from the project at any time and do not have to give a reason for withdrawing.
- I consent to participate in an interview with the researcher.
- I understand that my personal information will remain confidential to the researcher.
- I understand have the right to remain anonymous and not be identified by name.
- I have had the opportunity to have questions answered to my satisfaction.

Print Name of Interviewee:

Signature of Interviewee: \_\_\_\_\_ Date: \_\_\_\_\_

**Researcher Name:** Saud Alhumayn

**Contact Address:** University of Wolverhampton, Faculty of Science and Engineering,  
School of Architecture and the Built Environment, WV1 1LY

**Email Address:** [S.Alhumayn@wlv.ac.uk](mailto:S.Alhumayn@wlv.ac.uk)

## **INTERVIEW QUESTIONS**

- 1. Please can you tell me about your job, position and name of your organization?**
- 2. Please may I know in which sector of the construction your company mostly operates? What is the organization's speciality and area of operations?**
- 3. How do you communicate and share construction project information with the different members of the project team?**
- 4. In terms of sharing projects designs, does your organization use 3D models or still use 2D? Which other methods do you use?**
- 5. What are your opinions regarding the understanding of BIM?**
- 6. Are you aware of the potential benefits of BIM to your organization?**
- 7. In your opinion what do you think are the main barriers and fears for your organization in adopting BIM? Please can you elaborate?**
- 8. In your opinion what do you think are the main challenges facing or that could face BIM implementation in the Saudi construction industry? Please can you elaborate on how these could be addressed?**
- 9. In your opinion what do you think are the strategies for BIM adoption in KSA? How do you think the long-term benefits of BIM can be realised?**
- 10. Who do you think are the main actors to ensure the adoption of BIM in Saudi Arabia?**
- 11. What do you think is the government role in achieving successful BIM adoption in KSA?**
- 12. In your opinion is BIM education and training important to develop a core set of skills as a strategy for BIM adoption?**
- 13. So what type of training and education would you suggest?**

# APPENDIX 3: ACKNOWLEDGEMENT OF ETHICAL APPROVAL

Single response: Ethical Approval Form (Faculty of Science and Engineering)

Survey input field	Respondent's answer
<b>Name:</b>	SAUD ABDULLAH ALHUMAYN

**1. Please enter your surname and first name below. (SURNAME, FIRST NAME)**  
ALHUMAYN, SAUD

**2. Please enter your University email address (e.g. M.Name@wlv.ac.uk)**  
S.Alhumayn@wlv.ac.uk

**3. Please enter the name of your Director of Studies, Principal Investigator or, for Principal Investigators, your line manager.**  
Dr. Ezekiel Chinyio and Professor Issaka Ndekugri

**4. Please enter date by which a decision is required below. (Note that decisions can take up to 4 working weeks from date of submission)**  
February 2016

**5. Which subject area is your research / project located?**

1. **Architecture and Built Environment**
2. Biology, Chemistry and Forensic Science
3. Engineering
4. Life Sciences
5. Mathematics and Computer Science
6. other

**6. Please select your School**

1. **School of Architecture and Built Environment**
2. School of Biomedical Science and Physiology
3. School of Biology, Chemistry and Forensic Science
4. School of Engineering
5. School of Mathematics and Computer Science
6. School of Pharmacy
7. Other (please specify below)

**7. Does your research fit into any of the following security-sensitive categories? (For definition of security sensitive categories see RPU webpages ([www.wlv.ac.uk/rpu](http://www.wlv.ac.uk/rpu)) follow links to Ethical Guidance).**

1. commissioned by the military
2. commissioned under an EU security call
3. involve the acquisition of security clearances
4. concerns terrorist or extreme groups
5. **not applicable**

**8. Does your research involve the storage on a computer of any records, statements or other documents that can be interpreted as promoting or endorsing terrorist acts?**

1. YES
2. **NO**

**9. Might your research involve the electronic transmission (eg as an email attachment) of any records or statements that can be interpreted as promoting or endorsing terrorist acts?**

1. YES
2. **NO**

Approved 25/02/2016

**10. Do you agree to store electronically on a secure University file store any records or statements that can be interpreted as promoting or endorsing terrorist acts. Do you also agree to scan and upload any paper documents with the same sort of content. Access to this file store will be protected by a password unique to you. Please confirm you understand and agree to these conditions?**

1. **YES I understand and agree to the conditions**

2. NO (please explain below)

3. I do not understand the conditions

My data will not promote or endorse terrorism acts see question 9

**11. You agree NOT to transmit electronically to any third party documents in the University secure document store?**

1. **YES I agree**

2. NO I don't agree

**12. Will your research involve visits to websites that might be associated with extreme, or terrorist, organisations? (for definition of extreme or terrorist organisations see RPU webpages ([www.wlv.ac.uk/rpu](http://www.wlv.ac.uk/rpu)) and follow links to Ethical Guidance.**

1. YES (Please outline which websites and why you consider this necessary)

2. **NO**

**13. You are advised that visits to websites that might be associated with extreme or terrorist organisations may be subject to surveillance by the police. Accessing those sites from university IP addresses might lead to police enquiries. Do you understand this risk?**

1. **YES I understand**

2. NO I don't understand

**14. What is the title of your project?**

An investigation the extent of the use of BIM and to find strategies for more effective BIM adoption including an identification of the barriers in The Kingdom of Saudi Arabia.

**15. Briefly outline your project, stating the rationale, aims, research question / hypothesis, and expected outcomes. Max 300 words.**

RESEARCH AIM: To investigate the extent of the use of BIM and to find strategies for more effective BIM adoption including an identification of the barriers in The Kingdom of Saudi Arabia.

RESEARCH OBJECTIVES:

1. To identify the functionalities of BIM from literature review.

2. To use literature review to study the awareness of BIM in Saudi Arabia construction industry.

3. To investigate the use of BIM by Saudi construction organizations and identify it's most relevant enabling factors in the Saudi Arabian construction industry.

4. To empirically and critically examine and to describe the barriers to the use of BIM in Saudi Arabia.

5. To empirically investigate the strategies for avoiding or overcoming the barriers.

6. To draw conclusions from the foregoing and make recommendations to the Saudi construction industry regarding the future use of BIM in order to achieve better construction outcomes.

RESEARCH RATIONALE:

The Saudi Arabian construction industry is often considered to lag behind other sectors in terms of its ability to take on new innovative technologies. A number of the Saudi construction industry characteristics have been offered as the rationale for this problem, such as the largely bespoke nature of its products and services, and the heterogeneous nature of its knowledge boundaries coupled with transient project teams (Anumba and Pulsifer, 2010). The slow roll out of BIM solutions on projects reflect the experimental and exploratory nature of the development of new innovative technological solutions in the Saudi construction industry (Davies and



Harty, 2012). Indeed, the outcome of BIM implementation is not just based on the change of technology, but the change of task, structure and personnel.

Hence the theoretical challenge is to overcome barriers posed by both the technology and organisation and allow for the analysis of their interactive combination in generating condition for Saudi organisational configuration and reformation. Accordingly the central issue to be analysed and discussed in this research is how an enhanced understanding of BIM and its implementation in Saudi construction organisations can be gained.

#### **16. How will your research be conducted?**

**Describe the methods so that it can be easily understood by the ethics committee. Please ensure you clearly explain any acronyms and subject specific terminology. Max 300 words**

The theoretical foundation for the research will be built on a wide ranging literature review with the use of textbook, journal articles, conference papers and reports and proceeding papers. The goal is to provide an extensive background for understanding the functionalities of BIM.

A questionnaire survey will be used to gather the primary data for the research. Overall this will assist in defining the goal of the extent of use of BIM in order to identify the awareness of BIM in the construction industry of Saudi Arabia. The sample population to be selected to participate in this survey are construction organizations operating in Saudi Arabia as well as Saudi construction personnel. The research sample for the questionnaire is to be chosen randomly. As the aim is to have an even distribution representative for the population.

The usage of the case study research method will supplement the questionnaire survey as an explanatory tool to investigate the benefits of BIM and how BIM can support the construction industry of Saudi Arabia. It is proposed that at least two case studies be carried out. The case studies will thus look at several issues: abstracting typical portions of the construction project, the rapid evolution of a simulation model, and the usefulness of using an active project as a basis for research, trying to give a full and rich description of relationships between different variables and factors whereby the building simulation is to be used to optimise various different facets in order to improve construction practices and standards, as well as gaining an insight into the benefits of BIM in the construction industry of Saudi Arabia.

#### **17. Is ethical approval required by an external agency? (e.g. NHS, company, other university, etc)**

1. **NO**
2. YES - but ethical approval has not yet been obtained
3. YES - see contact details below of person who can verify that ethical approval has been obtained)

#### **18. What in your view are the ethical considerations involved in this project? (e.g. confidentiality, consent, risk, physical or psychological harm, etc.) Please explain in full sentences. Do not simply list the issues. (Maximum 100) words)**

For this research the only ethical consideration is participant confidentiality.

#### **19. Have participants been/will participants be, fully informed of the risks and benefits of participating and of their right to refuse participation or withdraw from the research at any time?**

1. **YES (Outline your procedures for informing participants in the space below.**
2. NO (Use the space below to explain why)
3. Not applicable - There are no participants in this study

All participants will be fully informed by use of a cover letter which will be explaining the data protection arrangement.

#### **20. Are participants in your study going to be recruited from a potentially vulnerable group? (See RPU website ([www.wlv.ac.uk/rpu](http://www.wlv.ac.uk/rpu)) and follow link to Ethical Guidance pages for definition of vulnerable groups )**

1. YES (Describe below which groups and what measures you will take to respect their rights and safeguard them)
2. **NO**

#### **21. How will you ensure that the identity of your participants is protected (See RPU website ([www.wlv.ac.uk/rpu](http://www.wlv.ac.uk/rpu)) and follow link to Ethical Guidance pages for guidance on**

**anonymity)**

Names will be asked but codes will be used to identify respondents in the treatment and analysis data. Only me and my supervisors have access to the research data.

**22. How will you ensure that data remains confidential ((See RPU website ([www.wlv.ac.uk/rpu](http://www.wlv.ac.uk/rpu)) and follow link to Ethical Guidance pages for definition of confidentiality)**

Only the researcher will have access to the data I have collected at all times. The data will be stored in a folder that can be access by password that be known by me only.

**23. How will you store your data during and after the project? (See RPU website ([www.wlv.ac.uk/rpu](http://www.wlv.ac.uk/rpu)) and follow link to Ethical Guidance pages for definition of and guidance on data protection and storage).**

All data will be stored electronically on laptop and external hard drive which will be in the researchers possession at all the times. And all data will be protected by password.